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Part VIII

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ROTOR-BEARING DYNAMICS

TECHNOLOGY DESIGN GUIDE

**Part VIII A Computerized Retrieval System for Fluid
Film Bearings**

SHAKER RESEARCH

BALLSTON LAKE, NEW YORK 12019

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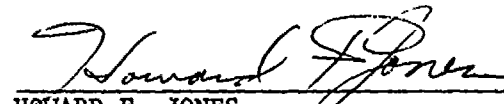
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This technical report has been reviewed and is approved for publication.


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→ the dimensional or the dimensionless form or to generate data lines in the sequence and format directly usable as input to the rotordynamics software described in AFAPL-TR-78-6, Part I. Inertia, compliance and damping effects of the pedestal can be included in the retrieval dynamic characteristics of each bearing. ←

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PREFACE

The work reported herein is for a partial fulfillment of USAF Contract No. AF33615-76-C-2038. Dr. Coda H. T. Pan, the Principal Investigator of the contract, was directly involved in the execution of the technical effort with the assistance of Mr. B. F. Geran, Ms. J. A. Bartlett, and Mr. S. Fiedler. The contract was initiated under Project 3048, "Fuels, Lubrication and Fire Protection," Task 304806, "Aerospace Lubrication," Work Unit 30480685, "Rotor-Bearing Dynamics Design."

The work reported herein was performed during the period March 1979 to March 1980 under the direction of John B. Schrand (AFWAL/POSL) and Dr. James F. Dill (AFWAL/POSL), Project Engineers. The report was released by Shaker Research Corporation in April 1980.

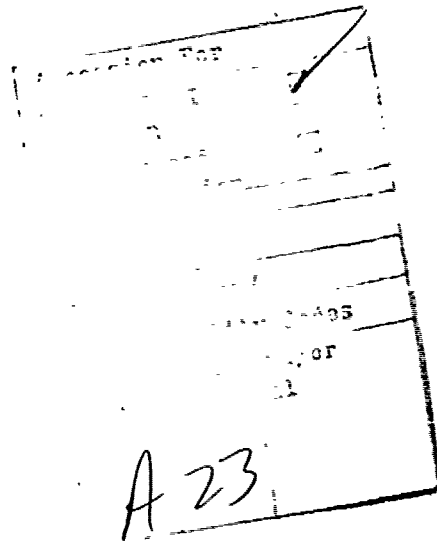


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NOMENCLATURE

a_o	near field constant
b_o	effective damping constant (lb-sec/in); far field constant
$B_{xx}, B_{xy}, \text{etc.}$	damping coefficients (lb-sec/in)
$[B]$	damping matrix (lb-sec/in)
$\bar{B}_{xx}, \bar{B}_{xy}, \text{etc.}$	$2\pi C\{\mu LD(R/C)^2\}^{-1} \times (B_{xx}, B_{xy}, \text{etc.})$
$[\bar{B}]$	$2\pi C\{\mu LD(R/C)^2\}^{-1} [B]$
C	radial arc clearance (in)
C_b	radial bearing clearance (in)
D	journal diameter (in)
e	eccentricity (in)
f	vibrational frequency (Hz)
F_x, F_y	components of bearing reaction force (lb)
F'_x, F'_y	components of perturbation bearing reaction (lb)
\tilde{F}_x, \tilde{F}_y	complex amplitudes of F'_x and F'_y for simple harmonic motion (lb)
G_x, G_y	complex coefficients in the governing equation for the eigenvector
J_p	pitching mass moment of inertia of a tilting pad
\bar{J}	$J_p N_s [\mu(R/C)^2(LD)R]$
k_o	effective stiffness constant (lb/in)
$K_{xx}, K_{xy}, \text{etc.}$	stiffness coefficients (lb/in)
$[K]$	stiffness matrix (lb/in)
$\bar{K}_{xx}, \bar{K}_{xy}, \text{etc.}$	$C\{\mu N_s LD(R/C)^2\}^{-1} \times (K_{xx}, K_{xy}, \text{etc.})$
$[\bar{K}]$	$C\{\mu N_s LD(R/C)^2\}^{-1} [K]$
L	bearing length (in)

$[M]$	inertia matrix ($\text{lb-sec}^2/\text{in}$)
m	preload, $1-C_b/C$
m_o	consistent mass ($\text{lb-sec}^2/\text{in}$)
N_s	rotor speed (rev/sec)
Q_{loss}	volume flow rate of lubricant lost by end leakage (in^3/sec)
Q_{required}	volume flow rate of lubricant (in^3/sec)
$\bar{Q}_{\text{loss}}, \bar{Q}_{\text{required}}$	$(N_s LDC)^{-1} (Q_{\text{loss}}, Q_{\text{required}})$
R	journal radius, $D/2$ (in)
S	Sommerfeld number, $\mu N_s LD(R/C)^2/W$
T	bearing friction torque (in-lb)
\bar{T}	$4TC/(\mu N_s D^3 L)$
u_o	amplitude of δ_{xo}
U_x, U_y	real parts of G_x and G_y , respectively
V_x, V_y	imaginary parts of G_x and G_y , respectively
\underline{w}	vector symbol for (δ_x, δ_y)
\underline{w}_o	vector symbol for $(\delta_{xo}, \delta_{yo})$
W	static load magnitude (lbs)
\bar{W}	$1/S$, static equilibrium load parameter
x, y	Cartesian coordinates of the journal bearing in the radial plane; x is along the direction of load, rotation is counterclockwise
X, Y	global Cartesian coordinates of the rotor in the radial plane
$[Z]$	$[K] = i [B]$

α	load scaling parameter for L/D variation
γ_o	argument of $\tilde{\delta}_{xo}$
δ_{xo}, δ_{yo}	components of static displacement (in)
δ'_x, δ'_y	components of perturbation displacement (in)
$\dot{\delta}_x, \dot{\delta}_y$	components of perturbation velocity (in/sec)
$\tilde{\delta}_x, \tilde{\delta}_y$	complex amplitudes of $\tilde{\delta}_x$ and $\tilde{\delta}_y$ for simple harmonic motion (in)
ϵ	e/C , eccentricity ratio of bearing arc
ϵ	e/C_b , eccentricity ratio of assembled bearing
μ	viscosity coefficient of lubricant (Reyns)
ν	frequency of oscillation (radians/sec)
ω	rotational speed (radians/sec)
ψ	attitude angle (deg)
τ	$\frac{2}{\pi} \tan^{-1}(\bar{W})$, load parameter function
θ_p	angular location of pivot or preload line measured from the leading edge of a bearing pad arc angle of bearing pad
χ	arc angle of bearing pad (deg)

Subscripts

Arg { }	Argument of the complex quantity { }
b	rigidly mounted bearing
o	natural orbit
p	pedestal
(')	time derivative

SECTION I

INTRODUCTION

Reliable prediction of the dynamic behavior of a rotor system supported by fluid film bearings (e.g., critical speeds and resonant frequencies, damped response to mass imbalance and other forms of dynamic excitation, and threshold of self-excited instability) depends on an accurate knowledge of the dynamic restraining characteristics of each bearing, which are represented by a set of eight dynamic perturbation coefficients (stiffness and damping coefficients with cross-coupling effects). Given the details of the bearing design (e.g., diameter, length, nominal operating clearance, gap geometry), lubricant viscosity and its temperature dependence, operating speed, and the lubricant film temperature, one can in principle compute steady state performance parameters (e.g., minimum gap, bearing friction, lubricant flow rate) and the dynamic perturbation coefficients. Typically, it is necessary to resort to some numerical technique in such computations. In the previous issue of the Rotor-Bearing Dynamics Technology Design Guide, one volume dealt with the calculation of performance parameters and perturbation coefficients for circular arc journal bearings operating with an incompressible lubricant [1]. Since then, other sources for such computations have also become available either as software furnished in its entirety or by allowing the user to access installed software at a computer center [2]. Some of the software have the capability of accommodating special features in the gap geometry. The proliferation efforts of such software has not yet reached a well-defined trend. Even with the availability of such software, the computation of a set of data needed as input for a rotor-bearing dynamic analysis is not a totally trivial matter. The storage memory requirement is typically quite large. Accuracy of computed data is often sensitive to details in the input preparation which may be quite obscure to an inexperienced user. For these two reasons, it was decided not to link up the bearing computer software with the rotor dynamics software. Instead, as a part of the present effort to update the Rotor-Bearing Dynamics

Technology Design Guide, it was decided that the immediate attention should be directed toward the establishment of a procedure for the convenient extraction of the dynamic perturbation coefficients from a prepared data table. A basic data bank consisting of thirty-one tables for various incompressible fluid film bearings is described in another part of the new Design Guide [3]. The data bank can be readily appended with additional tables if so desired. The required procedures for extracting the desired dynamic perturbation coefficients and for installing additional data tables are described herein.

Gas lubricated fluid film bearings are also of interest in advanced aircraft turbo-propulsion systems. Recent technological efforts in this area are primarily concerned with gas bearings of the "foil" variety. Another part in the new Design Guide will be exclusively devoted to gas bearings for machinery applications [4].

SECTION II

DYNAMIC CHARACTERISTICS OF A JOURNAL BEARING

2.1 Static Equilibrium Condition

The dynamic perturbation coefficients of a journal bearing contains the information regarding the mutual interactions between the rotor and the bearing. The perturbation analysis of a dynamic system presumes the existence of a static equilibrium condition, and deals with the response to a dynamics excitation and/or whether the equilibrium condition is stable. Typically, the dynamic perturbation coefficients are dependent on the static equilibrium state. Parameters which define the static equilibrium condition of a journal bearing are illustrated in Fig. 1, which depicts the cross-sectional view of the space between the journal, the portion of shaft which passes through the bearing bushing, and the bushing inner surface, which is shown as a circle for the present purpose.

In the lateral plane, the x-axis of a two-dimensional right-handed Cartesian coordinate system is oriented along the direction of the static load W . Sense of rotation is by convention required to be counterclockwise. Under load, the journal center is displaced from the bearing center. The amplitude of the displacement is called bearing eccentricity e . It is a peculiarity of the fluid film bearing that the displacement vector is not necessarily parallel to the load vector. The angle measured from the load vector to the displacement vector (in the counterclockwise direction) is called the attitude angle ψ .

The overall geometry of the journal bearing is described by three dimensions; namely, the length L , the diameter D , and the clearance C . There is some variance in the literature regarding the connotation of the clearance. In the present document, it represents the radial distance between the journal surface and the bushing surface (or a portion thereof) when the centers of curvature of the two surfaces are made coincident. The operating condition of the journal bearing

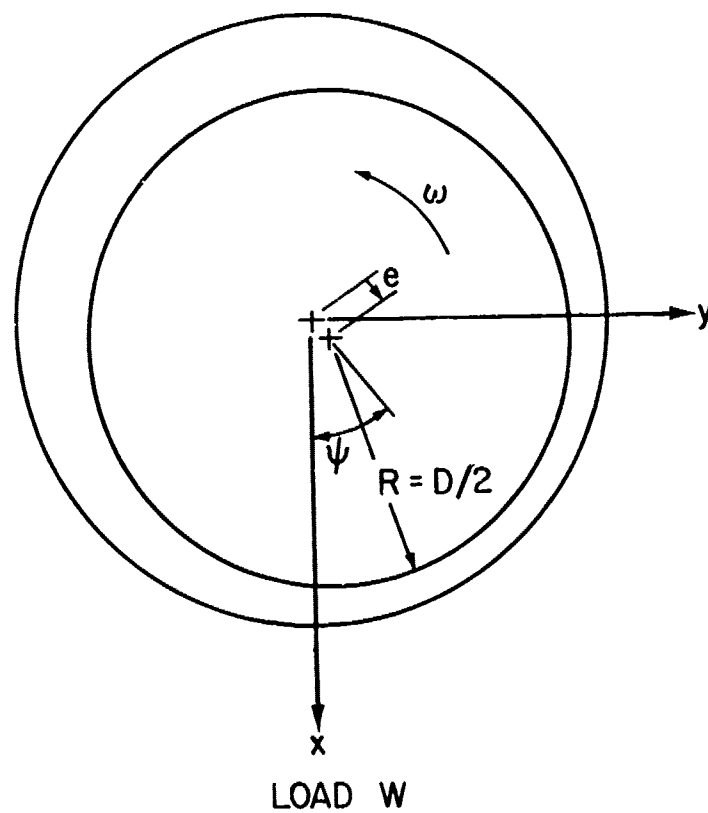


Figure 1 Static Equilibrium Condition of a Journal Bearing

is defined in terms of the rotational speed N_s (in units of revolution per sec) and the lateral load W (in pounds).

It is also necessary to specify the lubricant viscosity, which in turn is temperature dependent. Actually the lubricant temperature varies not only across the film thickness, but also along the passage through the bearing gap. Since it is impractical to allow for actual temperature dependence of viscosity in the computation of bearing operation characteristics, it is necessary to exercise a judicious judgment in specifying the effective temperature level. In principle, a heat balance can be performed among friction heat generation, convection cooling by the lubricant flow, and conduction cooling through journal and bushing surfaces. However, uncertainty in the operating temperature level itself is typically sufficient to obscure other considerations. Therefore, for the present purpose, it is recommended that high-low estimates of the operating temperature be used for the determination of the effective lubricant viscosity in lieu of a more thorough treatment of the thermal problem.

In order to allow general applicability to bearings possessing geometrical similarity irrespective of size, clearance to radius ratio, lubricant viscosity, and rotor speed, a data table is compiled in terms of dimensionless variables. Such dimensionless representation lends the data naturally to scaling in accordance with first principles. Among the parameters which represent the static equilibrium condition, specification of the load vector is sufficient. Other parameters are unique functions of the load vector (in the dimensionless representation). The directional parameter of the load vector relates to a reference axis which is peculiar to the bearing geometry. A plain circular bearing does not have such a reference axis due to its rotational symmetry; therefore, the load parameter is complete in terms of amplitude only. For other bearings (e.g., the two-lobe configuration) the direction of the load vector measured from a suitable reference

axis of the particular configuration is also a relevant parameter. The Sommerfeld number

$$S = \frac{\mu N_S LD(R/C)^2}{W} \quad (1)$$

which is a natural parameter in any solution of the lubrication equation for a journal bearing, can be directly utilized to represent the amplitude of the static load. The latter appears in the right-hand side of Eq. (1), while all other quantities are presumably known for a specific problem. Note that the journal diameter D is customarily represented in conjunction with the bearing length L to describe the projected area; at the same time, the journal radius R also appears in a ratio with the clearance C . In fact a bearing engineer often thinks of (LD) and (C/R) as independent design parameters. The reciprocal of the Sommerfeld number is customarily accepted as the dimensionless representation of the static load (amplitude) and is sometimes referred to as the load parameter:

$$\bar{W} = 1/S = \frac{W}{\mu N_S LD(R/C)^2} \quad (2)$$

A brief comment on the applicable units is in order in view of the common addiction to "English units" of American and British engineers amidst the worldwide movement toward standardization via the SI units. In the "English" convention, W would be in lbs. while the consistent unit for μ is $\text{Reyns} = \text{lb-sec/in}^2$. If SI units are to be adhered to, then W should be in Newtons ($1 \text{ N} = 0.22482 \text{ lb}$) and μ in Pascal-sec ($1 \text{ Pa} = 1 \text{ N/m}^2 = 1.45038 \times 10^{-4} \text{ lb/in}^2$). For the reader who is more used to cgs units, it may be of interest to note

$$\begin{aligned} 1 \text{ centipoise} &= 1.45038 \times 10^{-7} \text{ Reyns} \\ &= 0.001 \text{ Pa-sec} \\ 1 \text{ centipoise} &= 0.001 \text{ Pa-sec} = 1.45038 \times 10^{-7} \text{ Reyns} \end{aligned}$$

Other operating parameters for the static equilibrium condition are unique functions of S or \bar{W} . Although they do not directly contribute to the dynamic perturbation problems, they are included in the data table for completeness. They are defined in the dimensionless representation as follows without further elaboration.

Eccentricity

$$\text{Pad Eccentricity Ratio } \epsilon = e/C \quad (3a)$$

$$\text{Bearing Eccentricity Ratio } \epsilon_b = e/C_b \quad (3b)$$

C_b is the largest radius which the journal center can circumscribe in an assembled bearing.

Attitude Angle

ψ (customarily given in deg)

Torque

$$\bar{T} = \frac{4TC}{\mu N_s D^3 L} \quad (4)$$

T is the frictional torque experienced by the bearing.

Lubricant Flow Rate

$$\bar{Q}_{\text{required}} = \frac{Q_{\text{required}}}{N_s LDC} \quad (5)$$

$$\bar{Q}_{\text{loss}} = \frac{Q_{\text{loss}}}{N_s LDC}$$

Q_{required} is the volume flow rate which passes through the bearing inlet edge. Q_{loss} is the volume flow rate leaving the bearing gap through its ends. The excess of Q_{required} over Q_{loss} is the recirculation flow rate.

2.2 Dynamic Perturbations

The perturbation point of view requires that the deviation of the force of interaction between the rotor and the bearing from the equilibrium value be sufficiently small to permit use of the method of linear superposition in the dynamic analysis. The measure of "smallness" is that the amplitude of the perturbation displacement at any instant be a small fraction of the minimum film thickness. Dynamic analysis requires allowance for time-dependence. In the case of incompressible fluid film bearings, time-dependence is associated with squeeze film effects which correspond to velocity perturbations. Combined displacement and velocity perturbations are illustrated in Fig. 2. Displacement components (δ'_x, δ'_y) and velocity components $(\dot{\delta}_x, \dot{\delta}_y)$ form a complete set of perturbation parameters. The instantaneous bearing reaction has the components

$$F_x = -W + F'_x$$

$$F_y = F'_y$$

While the static equilibrium displacement is determined by $e = C\epsilon$ and ψ , both ϵ and ψ being unique functions of $\bar{W} = W(C/R)^2/(\mu N_s LD)$, the perturbation hypothesis allows one to express the perturbation reaction components to be

$$\begin{aligned} F'_x = & -K_{xx} \delta'_x - B_{xx} \dot{\delta}_x \\ & -K_{xy} \delta'_y - B_{xy} \dot{\delta}_y \end{aligned} \quad (7a)$$

$$\begin{aligned} F'_y = & -K_{yx} \delta'_x - B_{yx} \dot{\delta}_x \\ & -K_{yy} \delta'_y - B_{yy} \dot{\delta}_y \end{aligned} \quad (7b)$$

The complete set of perturbation coefficients includes the stiffness coefficients $(K_{xx}, K_{xy}, K_{yx}, K_{yy})$ and the damping coefficients

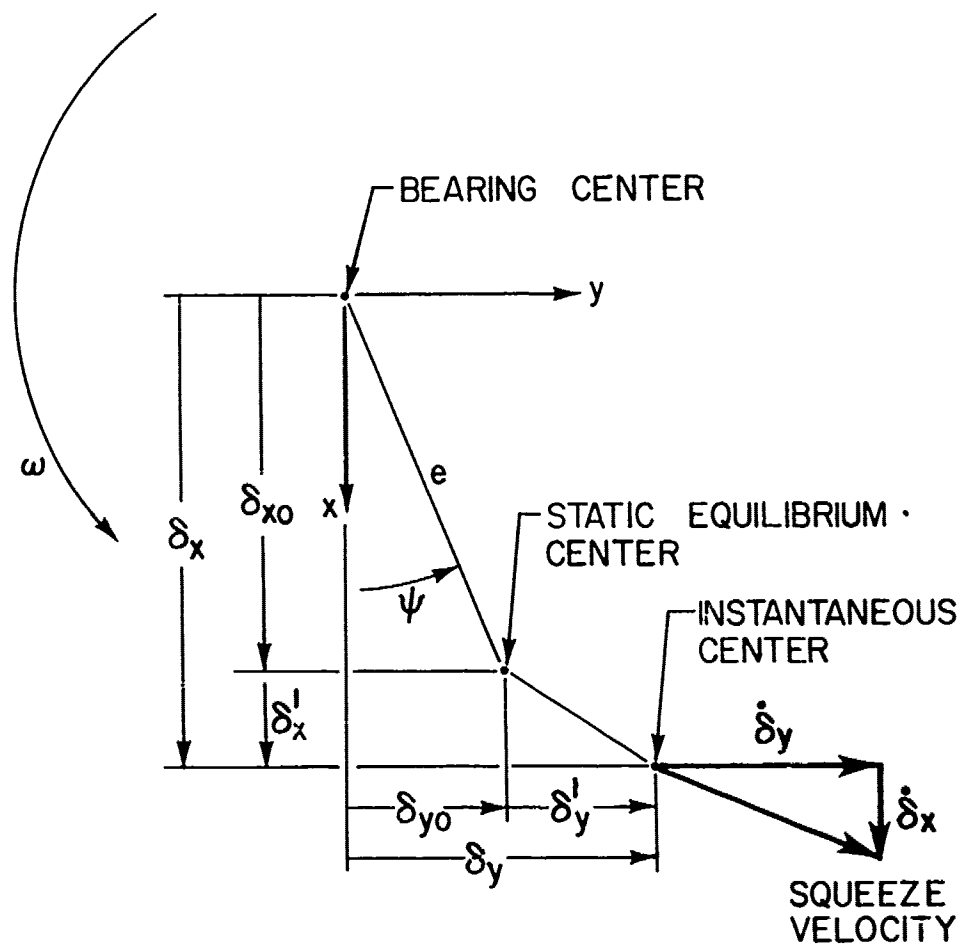


Figure 2 Displacement and Kinematic Perturbation Vectors

(B_{xx} , B_{xy} , B_{yx} , B_{yy}). Double subscripts are necessary because the perturbation reaction is not necessarily co-linear with either the perturbation displacement or the perturbation velocity. The first subscript denotes the direction of the reaction, and the second subscript represents the direction of the perturbation parameter. The stiffness coefficients are associated with displacement perturbations while the damping coefficients are associated with kinematic (velocity) perturbations. It is customary to employ the notations of matrix algebra to write

$$\begin{bmatrix} K \end{bmatrix} = \begin{bmatrix} K_{xx} & K_{xy} \\ K_{yx} & K_{yy} \end{bmatrix}; \quad \begin{bmatrix} B \end{bmatrix} = \begin{bmatrix} B_{xx} & B_{xy} \\ B_{yx} & B_{yy} \end{bmatrix} \quad (8)$$

The perturbation coefficients are obtained by solving the lubrication equation which is linearized with respect to each of the eight perturbation parameters one at a time, then integrating the film pressure with the appropriate projection of bearing surface.

The perturbation coefficients can also be represented in the dimensionless form to allow dynamic scaling for geometrically similar bearings. Thus,

$$\begin{bmatrix} \bar{K} \end{bmatrix} = \left[\frac{\mu N_s LD(R/C)^2}{C} \right]^{-1} \begin{bmatrix} K \end{bmatrix} \quad (9a)$$

$$\begin{bmatrix} \bar{B} \end{bmatrix} = \left[\frac{\mu LD(R/C)^2}{2\pi C} \right]^{-1} \begin{bmatrix} B \end{bmatrix} \quad (9b)$$

From Eq. (2) one can write

$$\mu N_s LD(R/C)^2 = WS$$

Therefore, it may also be written

$$\begin{bmatrix} \bar{K} \end{bmatrix} = \left(\frac{C}{WS} \right) \begin{bmatrix} K \end{bmatrix}; \quad \begin{bmatrix} \bar{B} \end{bmatrix} = \left(\frac{\omega C}{WS} \right) \begin{bmatrix} B \end{bmatrix} \quad (10)$$

$\begin{bmatrix} K \end{bmatrix}$ and $\begin{bmatrix} B \end{bmatrix}$ clearly are dependent on the static equilibrium parameter \bar{W} .

2.3 Symmetry Law for the Damping Matrix

It has been shown that the damping matrix is symmetrical provided the boundary conditions of the perturbation problem are time invariant [5]; that is

$$\bar{B}_{yx} = \bar{B}_{xy} \quad (11)$$

Bearings with fixed film boundaries or with a cavitation break up boundary determined by the Swift-Stieber condition [6, 7] inherently obey this symmetry relationship. Some approximate computation schemes may not conform to this requirement but otherwise yield fairly suitable results [3]. For this reason, the data retrieval system enforces this symmetry condition by substituting

$$(\bar{B}_{xy})_{adj} = (\bar{B}_{yx})_{adj} = \frac{1}{2} (\bar{B}_{xy} + \bar{B}_{yx}) \quad (12)$$

in place of $(\bar{B}_{xy}, \bar{B}_{yx})$ which are directly extracted from a data table and may not have identical values. Clearly, a data table which already satisfies Eq. (11) is not affected by this adjustment.

2.4 Natural Orbits and Effective Stiffness/Damping Constants

2.4.1 General Case: $Z_{xy} Z_{yx} \neq 0$

Suppose the perturbation motion is simple harmonic so that

$$(\dot{\delta}_x, \dot{\delta}_y) = \text{Re} \{ (\tilde{\delta}_x, \tilde{\delta}_y) e^{i\omega t} \} \quad (13)$$

The corresponding perturbation reactions are

$$(\dot{F}_x, \dot{F}_y) = \text{Re} \{ (\tilde{F}_x, \tilde{F}_y) e^{i\omega t} \} \quad (14)$$

To make use of matrix notation, write

$$\underline{v} = \begin{Bmatrix} \delta_x \\ \delta_y \end{Bmatrix} ; \quad \underline{P} = \begin{Bmatrix} F_x \\ F_y \end{Bmatrix} \quad (15)$$

Given the stiffness and damping matrices, the perturbation reaction can be computed as

$$\underline{P} = -[\underline{K}] + i\nu [\underline{B}] \underline{w} \quad (16)$$

One can seek the condition of diagonalization of the above equation; i.e. provided the components of \underline{w} assume a special relative amplitude and phase relationship, one can write

$$\underline{P}_o = -(k_o + i\nu b_o) \underline{w}_o \quad (17)$$

Subscript "o" designates the special relationship which describes a natural orbit. The physical interpretation of Eq. (17) is that the bearing behaves like a spring-dashpot restraint if the perturbed motion is a natural orbit, the spring and dashpot constants being respectively k_o and b_o .

Given $[\underline{K}]$ and $[\underline{B}]$ of a bearing, k_o and b_o can be found at any frequency ν as roots of a complex eigenvalue problem. Accordingly, \underline{w}_o can be determined as the corresponding eigenvector. Upon first identifying \underline{P} and \underline{w} in Eq. (16) with \underline{P}_o and \underline{w}_o respectively, and then eliminating \underline{P}_o between Eqs. (16) and (17), one obtains the homogeneous equation

$$\left[\underline{K} + i\nu \underline{B} - (k_o + i\nu b_o) \underline{I} \right] \underline{w}_o = \underline{0} \quad (18)$$

$[\underline{I}]$ is the identity matrix with unity as its diagonal elements and null elements elsewhere. Disregarding the possibility that \underline{w}_o may be a null vector, the characteristic determinant should vanish. k_o and b_o are roots of the characteristic determinant and are found as sets which are consistent

with the null condition of both real and imaginary parts of the characteristic determinant. The characteristic determinant is

$$\{Z_{xx} - (k_o + ivb_o)\}\{Z_{yy} - (k_o + ivb_o)\} - Z_{xy}Z_{yx} = 0 \quad (19)$$

where, $Z_{xx} = K_{xx} + ivB_{xx}$, etc.; and an explicit solution can be found as

$$k_o + ivb_o = \frac{1}{2} (Z_{xx} + Z_{yy}) \pm Z_o \quad (20)$$

where

$$Z_o = \frac{1}{2} \sqrt{(Z_{xx} - Z_{yy})^2 + 4 Z_{xy}Z_{yx}} \quad (21)$$

By convention, Z_o has a non-negative real part. The alternate signs in Eq. (20) yield two independent sets of (k_o, vb_o) . One may observe that the imaginary part of the right-hand side of Eq. (20) may not vanish with v . Thus, it is more appropriate to keep v and b together as a product. It is sometimes useful to define $\beta_o = (vb_o)/(2k_o)$ as the critical damping ratio of the natural orbit, which is related to the amplitude decrement factor of an unrestrained natural motion per cycle.

Corresponding to the two sets of (k_o, vb_o) , there are two eigenvectors, which are defined by

$$\left\{ \frac{1}{2}(Z_{xx} - Z_{yy}) \pm Z_o \right\} \bar{\delta}_{xo} + Z_{xy} \bar{\delta}_{yo} = 0 \quad (22a)$$

or, alternately,

$$Z_{yx} \bar{\delta}_{xo} - \left\{ \frac{1}{2}(Z_{xx} - Z_{yy}) \pm Z_o \right\} \bar{\delta}_{yo} = 0 \quad (22b)$$

These two equations are equivalent by virtue of Eq. (19). Only in the case of very special conditions, e.g., $Z_{xy}Z_{yx} = 0$ and/or $Z_{xx} - Z_{yy} = 0$, is it necessary to treat both of them to compute the eigenvector. The eigenvector is indeterminate by an arbitrary complex factor. Therefore, one is at liberty to invoke some ad hoc scaling and phasing rules; such as

$$|\tilde{\delta}_{xo}| \div |\tilde{\delta}_{yo}| = 1 \quad (23)$$

$$\text{Arg}\{\tilde{\delta}_{xo}\} + \text{Arg}\{\tilde{\delta}_{yo}\} = 0 \quad (24)$$

which sets the eigenvector to be

$$\underline{w}_0 = \begin{Bmatrix} u_0 e^{i\gamma_0} \\ (1-u_0) e^{-i\gamma_0} \end{Bmatrix} \quad (25)$$

u_0 (which has a non-negative value bounded by unity) and γ_0 (which is one-half the relative phase between the two degrees of freedom) remain to be found. In order to avoid writing lengthy algebraic expressions, in place of Eq. (22a) or Eq. (22b), let the governing equation for the eigenvector be

$$G_x \tilde{\delta}_{xo} + G_y \tilde{\delta}_{yo} = 0 \quad (26)$$

where

$$G_x = U_x + iV_x ; \quad G_y = U_y + iV_y \quad (27)$$

are complex quantities. Substitution of Eq. (25) into Eq. (26) then sets real and imaginary parts separately to zero, and one finds

$$\{U_x u_o + U_y (1-u_o)\} \cos \gamma_o - \{V_x u_o - V_y (1-u_o)\} \sin \gamma_o = 0$$

$$\{V_x u_o + V_y (1-u_o)\} \cos \gamma_o + \{U_x u_o - U_y (1-u_o)\} \sin \gamma_o = 0$$

They yield, after some straightforward algebraic manipulations

$$u_o = \frac{|G_y|}{|G_x| + |G_y|} ; \quad 1-u_o = \frac{|G_x|}{|G_x| + |G_y|} \quad (28)$$

$$\gamma_o = \tan^{-1} \frac{(U_x |G_y| + U_y |G_x|)}{(V_x |G_y| - V_y |G_x|)} \quad (29)$$

The principal value of Eq. (29) would be used. The eigenvector as defined by Eq. (25, 28, 29) is thus far presented in terms of a Cartesian coordinate system. It describes an elliptical orbit with the sense of whirl governed by γ_o . The sense of whirl is positive; i.e., same as the sense of shaft rotation, if γ_o is in either the first or the third quadrant; and the sense of whirl is negative or opposite to that of shaft rotation if γ_o is in either the second or the fourth quadrant. In other words, the sense of whirl has the same sign as

$$\tan \gamma_o = \frac{U_x |G_y| + U_y |G_x|}{V_x |G_y| - V_y |G_x|}$$

If either Z_{xy} or Z_{yx} or both should vanish, the formulations presented above are not workable because both G_x and G_y would also vanish, rendering Eqs. (28) and (29) indeterminate. These are special cases and require separate attention.

2.4.2 No Cross-coupling: $Z_{xy} = 0, Z_{yx} = 0$

The homogeneous system of Eq. (18) becomes

$$\begin{pmatrix} Z_{xx} - (k_o + ivb_o) & 0 \\ 0 & Z_{yy} - (k_o + ivb_o) \end{pmatrix} \begin{pmatrix} \tilde{\delta}_{xo} \\ \tilde{\delta}_{yo} \end{pmatrix} = 0$$

Since the two degrees of freedom are totally uncoupled, the desired eigenvalue/vector sets are simply

$$k_o + ivb_o = Z_{xx}; \quad \tilde{\delta}_{xo} = 1, \quad \tilde{\delta}_{yo} = 0 \quad (31a)$$

and

$$k_o + ivb_o = Z_{yy}; \quad \tilde{\delta}_{xo} = 0, \quad \tilde{\delta}_{yo} = 1 \quad (31b)$$

2.4.3 Pseudo Uncoupled Case

One of Z_{xy} and Z_{yx} is zero, the other one is not. Write

$$Z_{jk} = 0; \quad Z_{kj} \neq 0 \quad (32)$$

The indices j or k may denote either x or y . They are always distinct. (Repeated indices designate a diagonal term; the implicit summation convention of indicial contraction is not used here.)

Eq. (18) is reduced to

$$\{Z_{jj} - (k_o + ivb_o)\} \tilde{\delta}_{jo} = 0 \quad (33)$$

$$Z_{kj} \tilde{\delta}_{jo} + \{Z_{kk} - (k_o + ivb_o)\} \tilde{\delta}_{ko} = 0 \quad (34)$$

Eq. (33) can be satisfied by two conditions. The first one is

$$k_o + ivb_o = Z_{jj} \quad (35)$$

Consequently, substituting into Eq. (34)

$$Z_{kj} \tilde{\delta}_{jo} + (Z_{kk} - Z_{jj}) \tilde{\delta}_{ko} = 0 \quad (36a)$$

Following steps previously used to describe Eqs. (28) and (29), from Eq. (26), one finds

$$|\tilde{\delta}_{jo}| = \frac{|Z_{kk} - Z_{jj}|}{|Z_{kj}| + |Z_{kk} - Z_{jj}|} ; \quad |\tilde{\delta}_{ko}| = \frac{|Z_{kj}|}{|Z_{kj}| + |Z_{kk} - Z_{jj}|} \quad (37a)$$

$$\text{Arg}\{\tilde{\delta}_{jo}\} = -\text{Arg}\{\tilde{\delta}_{ko}\}$$

$$= \tan^{-1} \left[\frac{K_{kj} |Z_{kk} - Z_{jj}| + (K_{kk} - K_{jj}) |Z_{kj}|}{v(B_{kj} |Z_{kk} - Z_{jj}| - (B_{kk} - B_{jj}) |Z_{kj}|)} \right] \quad (38a)$$

If Z_{kk} and Z_{jj} should happen to be equal, Eq. (38a) becomes indeterminate, at the same time $\tilde{\delta}_{jo}$ vanishes while $|\tilde{\delta}_{ko}|$ becomes unity. Actually, with $\tilde{\delta}_{jo}$ being zero, the argument of $\tilde{\delta}_{ko}$ has no physical significance and can be set to zero as an accepted convention.

The second condition which satisfies Eq. (33) is

$$\tilde{\delta}_{jo} = 0 \quad (37b)$$

Consequently, one can set

$$\tilde{\delta}_{ko} = 1 \quad (38b)$$

Then, upon substitution into Eq. (34), one obtains

$$k_o + ivb_o = z_{kk} \quad (35b)$$

Note that the second eigenvalue/vector set is indistinguishable from the first set under the conditions of $(z_{jk} = 0, z_{kj} \neq 0, z_{jj} = z_{kk})$ which represent a truly degenerate state since only one eigenvalue/vector set can be found for a two-degrees-of-freedom system.

The parameters $(\tilde{\delta}_{xo}, \tilde{\delta}_{yo})$ are Cartesian components of the natural orbit. Since every simple harmonic orbit takes on the shape of an ellipse, the natural orbit can be represented by:

- ratio of minor/major radii of the orbit, and
- inclination of the major axis from the x-axis

The relationships between the Cartesian components and the geometric parameters are derived in another part of the Rotor-Bearing Dynamics Technology Design Guide [9].

SECTION III

RETRIEVAL SYSTEM

3.1 Contents of the Bearing Data Bank

There are presently thirty-one (31) data tables in the collection of the data bank. Each data table represents one combination of configurations, geometrical parameters, and preload setting (if applicable). A summary of the contents of the data bank is contained in Table 1.

For bearings made up of partial arc pads, there is a setup parameter called preload, which measures the distance between the arc center and the bearing center as a fraction of the nominal clearance (pad clearance). As shown in Fig. 3, the bearing clearance C_b is smaller than the original arc clearance by the amount of preload mC . In this particular illustration, the preload is centrally directed, i.e., the line of centers bisect the pad arc. All data tables thus far collected have centrally preloaded pads.

For partial arc configurations, rotational symmetry is disrupted. The direction of the load vector is to be defined with reference to the arc geometry. A lobed bearing is made up of equally spaced arcs. The direction of the load vector is specified relative to the loaded arc. A two-lobe bearing is usually parted in a horizontal plane. Thus the gravity load is commonly directed along the bi-sector of the bottom arc. Such an arrangement is said to have a load "on pad." With an odd number of lobes, the usual practice is to place one more arc on the bottom than the top. Thus the load is directed between pads for the three-lobe bearing.

The tilting shoe bearing is described similarly as the lobed bearing. The preload parameter deals with the radial displacement of the pivot point. The angular location of the pivot is equivalent to the preload direction relative to the arc. It is known what the optimum pivot location is about 55% from the leading edge. However, if the pads should be erroneously in-

TABLE 1

CONTENTS OF DATA BANK

Bearing Type	Arc Angle	L/D	Notes	Preload	Data Table Number
Plain	360	0.50			PJ-05-1
2 Lobe	160	0.50	(1), (5)	0.00	ML2-05-1
				0.25	ML2-05-2
				0.50	ML2-05-3
3 Lobe	100	0.50	(2), (5)	0.00	ML3-05-1
				0.25	ML3-05-2
				0.50	ML3-05-3
4 Shoe Tilting Pad	80	0.25	(2), (3), (4)	0.00	TP4-02-1
				0.20	TP4-02-2
				0.30	TP4-02-3
				0.50	TP4-02-4
		0.50		0.00	TP4-05-1
				0.20	TP4-05-2
				0.30	TP4-05-3
				0.50	TP4-05-4
		1.00		0.00	TP4-10-1
				0.20	TP4-10-2
				0.30	TP4-10-3
				0.50	TP4-10-4

LEGEND:

- (1) Load on pad
- (2) Load between pads
- (3) Centrally pivoted
- (4) Synchronous frequency only,
and shoe inertia is neglected
- (5) Centrally preloaded

TABLE 1 - CONTENTS OF DATA BANK (continued)

Bearing Type	Arc Angle	L/D	Notes	Preload	Data Table Number
5 Shoe Tilting Pad	55	0.25	(1), (3), (4)	0.00	TP5-02-1
				0.20	TP5-02-2
				0.30	TP5-02-3
				0.50	TP5-02-4
		0.50		0.00	TP5-05-1
				0.20	TP5-05-2
				0.30	TP5-05-3
				0.50	TP5-05-4
		1.00		0.00	TP5-10-1
				0.20	TP5-10-2
				0.30	TP5-10-3
				0.50	TP5-10-4

LEGEND:

- (1) Load on pad
- (2) Load between pads
- (3) Centrally pivoted
- (4) Synchronous frequency only,
and shoe inertia is neglected
- (5) Centrally preloaded

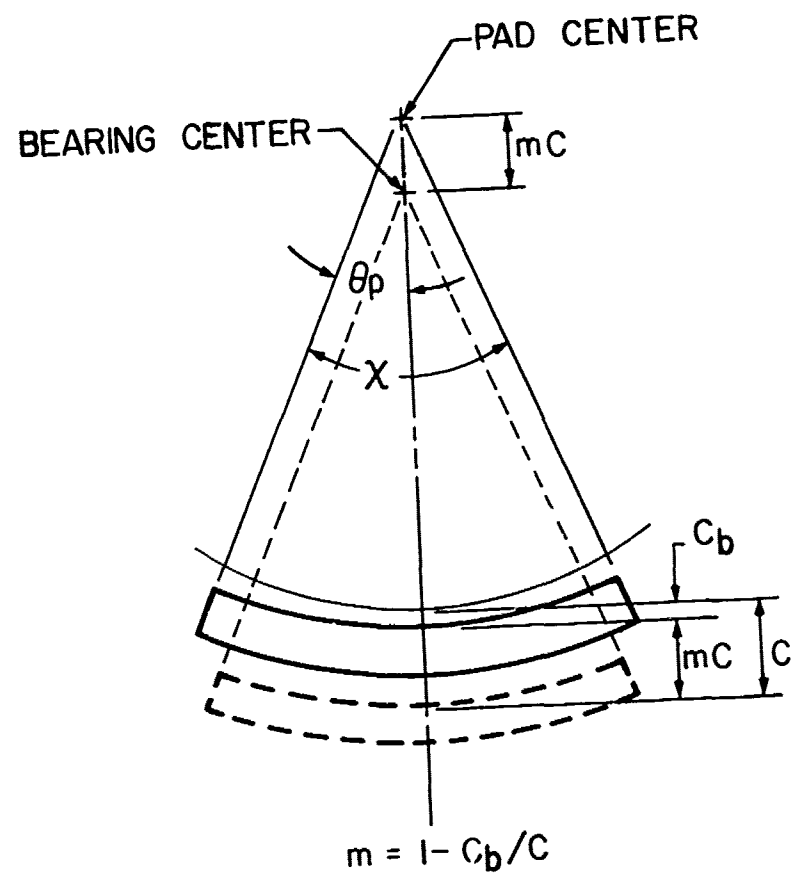


Figure 3 Centrally Preloaded Partial Arc ($\theta_p = \chi/2$)

stalled backwards, the load capacity of the bearing would be drastically smaller. The centrally pivoted arrangement is error safe since it acts identically if reversed. The tilting shoe bearings in the present data bank are all centrally pivoted.

An ideal pivot is incapable of exerting moment to the bearing pad. This condition adds two additional parameters for a complete definition of the dynamic data; namely,

$$\bar{J} = \frac{J_p N_s}{\mu(R/C)^2 (LD)R} \quad (39)$$

$$\bar{v} = f/N_s \quad (40)$$

which relate to the pitch moment of inertia of a bearing pad and the ratio of the vibrational frequency to the rotation frequency, respectively.

In the present data, ($\bar{J} = 0$ and $\bar{v} = 1$) are imposed. The inertialess assumption is usually adequate since the inertia of each pad should be quite small in comparison with the rotor inertia. An exception is the unloaded shoe, which would become vulnerable to the pathological condition of shoe fluttering. For this reason, tilting shoe bearings should always be preloaded. The data tables for the unloaded tilting shoe bearings are included mainly for reference. The nature of frequency dependance of the perturbation coefficients of tilting shoe bearings in effect reflects the phase relationships between the rotor motion and the pitching motions of the shoes. Fortunately, the total resultant of all shoes does not significantly vary with frequency. Therefore, the synchronous data ($\bar{v} = 1$) can be used for non-synchronous rotor dynamic studies with fair accuracy. If the precise data with allowance for shoe inertias and frequency dependance should be desired, the dynamic assembly procedure should be followed to synthesize the bearing characteristics from single pad characteristics [3].

All data tables in the present collection concern journal bearings which influence dynamics of the rotor system by reacting to lineal motions of the rotor. Some bearing support systems can react to angular motions of the rotor. A long journal bearing and a large thrust bearing runner are two such examples. In reacting to an angular motion of the rotor (in the radial plane), the bearing can provide a restraining moment. The required data parameters for such bearings are angular stiffness and angular damping coefficients which react to angular displacements and angular velocities, respectively. These coefficients also may induce anisotropic and cross-coupling features. The storage and retrieval methodologies described in this document can be readily adapted to handle angular bearings.

3.2 Interfacing Bearing Data with Rotor Dynamics Software

Each bearing data table is necessarily restricted to the following two conditions:

1. The bearing data is presented in a coordinate system which is peculiar to static load vector acting on the particular bearing.
2. The pedestal of the bearing is assumed to be rigid.

The bearing data retrieval system incorporates an interfacing procedure which removes these restrictions.

The static load vectors of all bearings in a rotor system may not share the same direction. The following circumstances require that individual load directions be assigned to each bearing:

1. For an overhung rotor, if its center of gravity is outboard, the load vectors at the two bearings would have opposite directions.

2. Gyroscopic loads which occur during rapid maneuvers of a military aircraft, usually are oppositely directed at the two main support bearings.
3. Laterally coupled rotors (e.g., in a transmission box) exert force on each other and tend to cause load vectors at various bearings to assume distinct directions.
4. Misalignment loads (for rotors supported by three or more bearings) generally may not be co-planar with the gravity load.

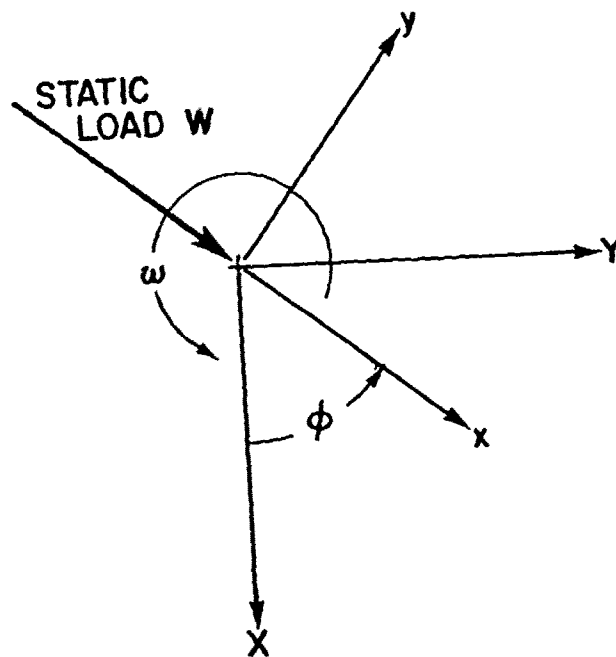
For these reasons, it is necessary to allow a deviation of the static bearing load vector from an axis of the global coordinates of the rotor:

Let (X, Y) and (x, y) , respectively, be global (rotor) and local (bearing) coordinate axes in the Cartesian representation, with the x -axis directed along the static load. Let ϕ be the angle measured from X to x as illustrated in Fig. 4. The transformation of a vector represented in the bearing coordinates to that represented in the rotor coordinates is given by the relation

$$\begin{bmatrix} X \\ Y \end{bmatrix} = \begin{bmatrix} \cos\phi & -\sin\phi \\ \sin\phi & \cos\phi \end{bmatrix} \begin{bmatrix} x \\ y \end{bmatrix} \quad (41)$$

Transformation of the stiffness and damping matrices is achieved by the following formula

$$\begin{bmatrix} K, B \end{bmatrix}_{\text{Rotor}} = \begin{bmatrix} \cos\phi & -\sin\phi \\ \sin\phi & \cos\phi \end{bmatrix} \begin{bmatrix} K, B \end{bmatrix}_{\text{Bearing}} \begin{bmatrix} \cos\phi & \sin\phi \\ -\sin\phi & \cos\phi \end{bmatrix} \quad (42)$$



XY ROTOR COORDINATES
 xy BEARING COORDINATES

Figure 4 Rotor and Bearing Coordinate Systems

Pedestal compliance and/or damping can contribute significantly to the rotor behavior. Pedestal compliance can be modelled in terms of lumped parameters.

$$\underline{\dot{Z}}_{-p} = \underline{\dot{K}}_{-p} + \underline{\dot{M}}_{-p} \frac{d^2}{dt^2} + \underline{\dot{B}}_{-p} \frac{d}{dt} \quad (43)$$

This is regarded as an operator for the displacement of the pedestal. The subscript "p" labels the pedestal effects. For a simple harmonic motion with the time dependence factor $\exp\{i\omega t\}$, Eq. (43) is reduced to

$$\underline{\dot{Z}}_{-p} = \underline{\dot{K}}_{-p} - \omega^2 \underline{\dot{M}}_{-p} + i\omega \underline{\dot{B}}_{-p} \quad (44)$$

Since the bearing reaction is directly transmitted to the pedestal

$$\underline{P} = -\underline{\dot{Z}}_{-b} \underline{\dot{w}}_{-b} - \underline{\dot{w}}_{-p} \quad (45a)$$

$$= -\underline{\dot{Z}}_{-p} \underline{\dot{w}}_{-p} \quad (45b)$$

$\underline{\dot{Z}}_{-b}$ is the impedance matrix of the (rigidly mounted) bearing. $\underline{\dot{w}}_{-b}$ and $\underline{\dot{w}}_{-p}$ are displacement vectors of the bearing and of the pedestal in the matrix notation, respectively. Eliminating \underline{P} between Eqs. (45a) and (45b), one finds

$$-\left[\underline{\dot{Z}}_{-b} \underline{\dot{w}}_{-b} + \underline{\dot{Z}}_{-p} + \underline{\dot{Z}}_{-b} \right] \underline{\dot{w}}_{-p} = 0$$

Solving for \underline{w}_p then substituting back into Eq. (45b), one obtains

$$\underline{p} = -[Z]_p \left[[Z]_p + [Z]_b \right]^{-1} [Z]_b \underline{w}_b \quad (46)$$

which in essence defines the effective support impedance as

$$[Z]_{\text{effective}} = [Z]_p \left[[Z]_p + [Z]_b \right]^{-1} [Z]_b \quad (47)$$

The retrieval software provides the user with an option to allow for pedestal compliance. Upon selecting this option, the user can furnish data consisting of up to ten numbers which define the elements of the three matrices $[K]_p$, $[B]_p$, and $[M]_p$. Upon extracting $[Z]_b$ from the data bank, Eq. (47) is executed by the interfacing software.

Aside from performing required coordinate transformations and incorporating pedestal compliance effects, the bearing data retrieval system also organizes the results in a tabular form consistent with the input format of the rotor dynamics software [9].

3.3 The Retrieval Procedure

The Fluid Film Bearing Data Bank is designed to furnish numerical information of bearing support characteristics needed in the performance of a variety of rotordynamic studies. The software for data retrieval requires the user to furnish the following input:

1. Location of Data Table -- The user has the choice of selecting a data table from the index of the available data bank or submitting the data bank to the file management system of the computer center in advance of the retrieval run. In either case, the data table is a result of preparation for full range interpolation according to the method to be described in Section IV.

2. Design Parameters of the Bearing.

- o lubricant viscosity (centipoise)
- o bearing diameter (in)
- o bearing length (in)
- o clearance (in)

3. Operating Parameters of the Bearing.

- o load magnitude (lbs)
- o load direction defined by the angle measured from the vertical axis in the sense of shaft rotation (deg)
- o shaft rotational speed (rpm)
- o vibration frequency as may be needed in certain bearing support systems (Hz)

4. Pedestal Compliance Characteristics -- The user can elect to furnish lumped parameter data of the pedestal which define stiffness, damping, and mass matrices.

- o pedestal weight (lbs)
- o pedestal c.g. offsets in three directions (in)
- o pedestal angular weight moment of inertia in two planes (lb-in²)
- o pedestal stiffness constants in two planes (lbs/in or in-lb/rad)
- o pedestal damping constants in two planes (lbs-sec/in or in-lb-sec/rad)

The output of the retrieval software includes in tabular forms

1. Data sets compatible with the input format of the rotor-dynamics software [9],

2. Tabulation of the static bearing characteristics,
3. Tabulation of the dynamic bearing coefficients, and
4. Effective stiffness/damping constants and natural orbit parameters as described in Section 2.4.

Additional information pertaining to the use of the retrieval software is given in Appendix A.

3.4 Description of the Retrieval Table

The retrieval table of each bearing is furnished as a sequential FORTRAN file. Its contents include the following:

1. Alphanumeric Index - This contains the file designation, the file size or number of data points (including near- and far-field limits), L/D of the bearing, and the load scaling factor which is presently defaulted as 1.125.
2. Array of Working Parameters - This is stored as groups of seven floating point numbers, each occupying a field of eleven spaces.
3. Retrieval Data of Each of Thirteen Data Variables - The thirteen variables appear in the following order: eccentricity ratio, attitude angle, friction, required flow, lost flow, \bar{K}_{xx} , \bar{B}_{xx} , \bar{K}_{xy} , \bar{B}_{xy} , \bar{K}_{yx} , \bar{B}_{yx} , \bar{K}_{yy} , and \bar{B}_{yy} .

The retrieval data of each variable consists of numbers which are also stored in succession in groups of seven floating point numbers each occupying a field of eleven spaces. They are stored without interruption for each variable and include: near-field exponent s_1 , far-field exponent s_2 , near-field constant a_0 , far-field constant b_0 , then for each data interval a set of spline coefficients for each of the data intervals corresponding to the array of working parameters (the comparison function and its three derivatives with respect to the working

parameter), and the comparison function for the far-field limit which should always be unity.

Table 2 shows the contents of a typical retrieval file. Table 3 is a printout of the contents with appropriate headings. The load is computed from the working parameter (TAU) according to Eq. (62) described in the next section.

A complete listing of all retrieval files of the present data bank is given in Appendix D.

TABLE 2

RETRIEVAL FILE NO ML3-05-1

FILE SIZE = 17

TYPICAL RETRIEVAL FILE

L/D = 0.5000

ALFA = 1.1250

```

0.0000D-01 3.5768D-02 5.8456D-02 8.0138D-02 1.2718D-01 2 0721D-01 2.8602D-01
4.4623D-01 5.7427D-01 6.5943D-01 7.6051D-01 8.1662D-01 8.4578D-01 8.7580D-01
9.0640D-01 9.3739D-01 1.0000D 00
1.0000D 00 0.0000D-01 1.0001D 00 1.0000D 00 1.0000D 00-1 6502D 00 0.0000D-01
1.9803D 02 9.4249D-01-1.5236D 00 7.0830D 00-1.3293D 02 9.0948D-01-1.3971D 00
4.0671D 00-6.6448D 01 8.8003D-01-1.3245D 00 2.6264D 00 1 2060D 01 8 2085D-01
-1.1876D 00 3.1937D 00 1.3868D-02 7.3602D-01-9.3197D-01 3.1948D 00-1 7265D 00
6.7236D-01-6.8557D-01 3.0587D 00-3.4465D 00 5.9942D-01-2.3977D-01 2.5066D 00
6.8959D-01 5.8950D-01 8.6833D-02 2.5949D 00 5.2071D 00 6.0685D-01 3.2671D-01
3.0383D 00 1.0659D 01 6.5722D-01 6.8826D-01 4.1157D 00 2 4396D 01 7 0303D-01
9.5757D-01 5.4845D 00 2.6015D 01 7.3340D-01 1.1286D 00 6.2432D 00 3.4971D 01
7.7026D-01 1.3318D 00 7.2931D 00 6.2869D 01 8.1471D-01 1 5843D 00 9.2165D 00
3.4883D 01 8.6841D-01 1.8867D 00 1.0298D 01-1.6446D 02 1.0000D 00
0.0000D-01-5.0000D-01 9.0000D 01 1.0007D 02 1.0000D 00-2.2698D 00 0.0000D-01
5.0412D 02 9.2266D-01-1.9473D 00 1.8031D 01-4.9054D 02 8.8216D-01-1.6645D 00
6.9020D 00 4.2378D 01 8.4777D-01-1.5049D 00 7.8208D 00-4.8412D 01 7 8479D-01
-1.1905D 00 5.5436D 00-2.1033D 01 7.0546D-01-8.1422D-01 3 8601D 00-1 5182D 01
6.5205D-01-5.5717D-01 2.6638D 00-6.8634D 00 5.9227D-01-2.1849D-01 1 5642D 00
9.3216D-01 5.7744D-01-1.0573D-02 1.6835D 00 4.1808D 00 5 8307D-01 1 4796D-01
2.0396D 00 1.5715D 01 6 1115D-01 4.3440D-01 3.6280D 00 4 4005D 01 6 4253D-01
7.0720D-01 6.0969D 00 5.9916D 01 6.6600D-01 9.1050D-01 7.8443D 00 1.3540D 02
6.9748D-01 1.2070D 00 1.1909D 01 1.6682D 02 7.4078D-01 1.6494D 00 1.7013D 01
5.4840D 02 8.0278D-01 2.4400D 00 3.4008D 01-5.4315D 02 1.0000D 00
0.0000D-01 5.0000D-01 1.6463D 01 1.7306D 01 1.0000D 00 1 2603D 00 0 0000D-01
-3.1207D 02 1.0427D 00 1.0607D 00-1.1162D 01 3.5253D 02 1 0646D 00 8 9819D-01
-3.1636D 00-1.9538D 01 1.0933D 00 8.2500D-01-3.5872D 00 2.1639D 01 1 1185D 00
6.8020D-01-2.5694D 00 7.0205D 00 1.1653D 00 4.9704D-01-2 0075D 00 5.1224D 00
1.1987D 00 3.5475D-01-1.6038D 00-9.9900D-01 1 2342D 00 8 4981D-02-1 7639D 00
-9.9638D-01 1.2303D 00-1.4904D-01-1.8914D 00-3.7706D 00 1 2104D 00-3 2379D-01
-2.2126D 00-6.9700D 00 1.1651D 00-5.8304D-01-2.9171D 00 5.6677D 00 1.1280D 00
-7.3778D-01-2.5991D 00 4.7046D 01 1.1056D 00-7.9358D-01-1 2270D 00-9 1263D 01
1.0808D 00-8.7155D-01-3.9670D 00 4.5428D 02 1.0544D 00-7 8032D-01 9.9308D 00
-2.4352D 02 1.0338D 00-5.8950D-01 2.3839D 00-3.8074D 01 1 0000D 00
0.0000D-01 0.0000D-01 4.7133D 00 4.0711D 00 1.0000D 00 7 7286D-02 0.0000D-01
-2.9511D 01 1.0025D 00 5.8409D-02-1.0555D 00 1.0540D 01 1 0036D 00 3.7173D-02
-8.1640D-01 2.6434D 01 1.0043D 00 2.5686D-02-2.4323D-01-2 2245D 00 1.0052D 00
1.1783D-02-3.4787D-01 2.5114D 00 1.0052D 00-8.0156D-03-1.4687D-01 2 7507D 00
1.0044D 00-1.1048D-02 6.9898D-02-2 5357D-01 1 0033D 00-3 1042D-03 2 9274D-02
4.7336D-01 1.0033D 00 4.5244D-03 8 9884D-02-9.1681D-01 1 0039D 00 8.8545D-03
1.1804D-02 3 8665D-01 1.0050D 00 1.2023D-02 5.0886D-02 3 5435D-01 1 0057D 00
1.5435D-02 7.1766D-02-2.0676D 01 1.0061D 00 8.7061D-03-5 3224D-01 1 7294D 01
1.0062D 00 5.2980D-04-1.3025D-02-3.9162D 01 1 0060D 00-1 8204D-02-1 2111D 00
2.4203D 00 1.0049D 00-5.4574D-02-1.1361D 00 1 8145D 01 1 0000D 00
1.0000D 00 0.0000D-01 1.4902D 00 1.6170D 00 1 0000D 00-1 5480D 00 0 0000D-01
1.2753D 02 9.4560D-01-1.4665D 00 4.5616D 00-1.1867D 02 9.1327D-01-1 7935D 00
1.8691D 00 7.3618D 01 8.8362D-01-1.3357D 00 3 4653D 00-1 6203D 01 8.2435D-01
-1.1906D 00 2.7032D 00 7.5566D 00 7.3836D-01-9 5004D-01 3 3080D 00-4.6527D 00
6.7339D-01-7.0381D-01 2.9413D 00-2.4167D 00 5.9672D-01-2 6360D-01 2 5541D 00
7.0220D-01 5 8415D-01 6.9196D-02 2.6441D 00 4 6007D 00 6 0011D-01 3 1106D-01
3.0359D 00 1.1362D 01 6.4901D-01 6 7596D-01 4 1843D 00 3 1211D 01 6 9444D-01

```

Table 2 - Typical Retrieval File (continued)

9.59840-01 5.93540 00-7.64980 00 7.24930-01 1.12970 01 5 71230 00 5.44380 01
 7.61660-01 1.32570 00 7.34670 00 1.22550 01 8.0570 01 1 55620 00 7.72160 00
 2.62600 02 8.58960-01 1.92160 00 1.58600 01-2.5330 01 1 00000 00
 1 00000 00 2.50000 00-5.51020-01 9.01730-01-1.0000 01 2.43230 00 0.00000-01
 7.14870 02-9.07550-01 2.88960 00 2.55690 01-9.1410 02-8.37190-01 3.23440 00
 4.82830 00 5.04370 02-7.65070-01 3.45760 00 1.5760 01-2.28060 02-5.88930-01
 3.94690 00 5.03570 00-2.74540 00-2.57170-01 4.74110 00 4.81600 00-2.07240 02
 8.30000-02 4.07700 00-1.15170 01 5.96330 01 6.1250 01-2.99720 00-1.96300 00
 -1.10460 02 9.58280-01 1.84040 00-1.61060 01 1.09710 02 1 06790 00 8.66620-01
 -6.76390 00-6.06430 00 1.11990 00 1.51940-01-7.37690 00-4.48830-01 1.11680 00
 -2.62680-01-7.40200 00 4.85580 02 1.10800 00-2.72070-01 6 75760 00-6.38130 02
 1.10000 00-3.56750-01-1.23990 01 3.60490 02 1 08500 00-5 67380-01-1.36780 00
 -3.54810 02 1.06500 00-7.80150-01-1.23630 01 1.97470 02 1 00000 00
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 1.70920 01-1.90400 02 8.10880-01-2.35400 00 1.29640 01 2 14400 01 7.14860-01
 -1.72040 00 1.39730 01-7.14280 01 6.15820-01-8.30910-01 8 25640 00-7.32560 01
 5.70000-01-4.07720-01 2.48310 00-1.16670 01 5.28550-01-1 59640-01 6.13880-01
 1.07130 01 5.16890-01 6.77800-03 1.98550 00-1.78470 01 5.22830-01 1.11150-01
 4.65710-01 3.75050 01 5.42900-01 3.49820-01 4.25670 00-4 05850 00 5.69110-01
 5.82280-01 4.02900 00 5.26980 02 5.89980-01 9.23810-01 1 93960 01 1.21420 02
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 -4.36860 02 7.75000-01 3.20110 00 1.88130 01-3.00470 02 1 00000 00
 0 00000-01 2.00000 00 1.00280 00 2.43360 00 1.00000 00 2 52450-01 0.00000-01
 6.91070 02 1.01430 00 6.94500-01 2.47180 01-3.69210 02 1 03570 00 1.16030 00
 1.63410 01-1.16740 02 1.06450 00 1 48720 00 1.38100 01-1 40590 02 1 14730 00
 1.98130 00 7.19640 00-1.65110 02 1.31480 00 2.02840 00-6.01730 00-7.03340 00
 1.45540 00 1.53240 00-6.57160 00-2.44570 01 1 59980 00 1.65640-01-1.04900 01
 3 99550 01 1.54900 00-8.49970-01-5.37410 00 1.66200 00 1 45730 00-1 30160 00
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 1 13280 02 1.05100 00-1.00570 00 9.15610 00-1 46240 02 1 00000 00
 1 00000 00 1.50000 00 5.09600 00 4 37650 00 1.00000 00 5 06220-01 0 00000-01
 2 48290 02 1.02000 00 6.65040-01 8.88040 00-6.03110 02 1 03620 00 7 11290-01
 -4.80300 00 2.98320 02 1.05100 00 6.77270-01 1 66520 00-4 62670 01 1 08390 00
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 6 02490 00 1.19900 00-2.89850-01-2.15990 00 2.24920 01 1 16880 00-3.92220-01
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 -3 46740 02 1.03700 00-5 34780-01-2.69200 00 4 29970 01 1 00000 00
 0 00000-01 2 50000 00-2 27990 00 2 24600-01-1 00000 00 8 05130-01 0.00000-01
 -3 23570 02-9 73670-01 5 98150-01-1.15730 01-1 70630 02-9 63410-01 2.91660-01
 -1 54450 01 1.42840 03-9.58290-01 2 92540-01 1.55260 01-6 04090 02-9.37870-01
 3 54510-01-1 28920 01 2 33080 02-9 30830-01 6 92310-02 5 76220 00-1.04440 02
 -9 16000-01 1 99000-01-2.46890 00 9 52820 01-8.50500-01 1 02630 00 1.27960 01
 -2 46580 01-6.22830-01 2.46260 00 9 63910 00 2.29120 02-3 54580-01 4.11430 00
 2.91510 01-8.58090 01 1.95440-01 6.62250 02 2.04770 01 1 08610 02 6.02460-01
 7.94240 00 2.65720 01-7.57380 03 8 14060-01 5.49720 00-1 94280 02 5 20190 03
 9.15000-01 2.00890 00-3.81190 01 2.87570 02 9.60000-01 9 77120-01-2 93190 01
 7 65610 02 9.80000-01 4.36160-01-5 59290 00 8 93290 01 1 00000 00
 1.00000 00 1.50000 00 5.09600 00 4 37650 00 1.00000 00 5 06220-01 0 00000-01

(Sheet 2 of 3)

Table 2 - Typical Retrieval File (continued)

```

2.48280 02 1.02000 00 6.65040-01 8.88040 00-6.03110 02 1 03620 00 7 11290-01
-4.80300 00 2.98320 02 1.05100 00 6 77270-01 1 66520 00-4 62610 01 1 08390 00
7.04410-01-5.11290-01-2.15010 01 1 13680 00 5 94640-01-2 23200 00 3 28660 00
1.17700 00 4.28940-01-1.97300 00-5 98100 00 1.21630 00 3 60820-02-2 93120 00
6.02490 00 1.19900 00-2.89850-01-2 15980 00 2.24920 01 1 16880 00-3 92220-01
-2.44400-01 5.46480-01 1.12800 00-4.14130-01-1 89160-01-2 93900 01 1 10360 00
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1.07400 00-6.01870-01-9.09800 00 5 60500 02 1 05400 00-6 17850-01 8 05330 00
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1.00000 00 1.50000 00 4.72030 00 3.40070 00 1 00000 00 5 96250-01 0 00000-01
1.14530 02 1.02220 00 6 69510-01 4 09650 00-7 93320 02 1 03690 00 5 58270-01
-1.39020 01 7.43670 02 1.04700 00 4 31640-01 2 22200 00-1 30490 02 1 06150 00
3.91790-01-3.91650 00 2.91140 01 1.08880 00 1.71590-01-1 58650 00 7 40080 00
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-1.96350 00-4.65670 00 9.86000-01-5 84030-01-2.43420 00 1 20630 02 9 52950-01
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9.34000-01-1.30580-01 2.31740 00 4.00150 02 9 33000-01 1 27670-01 1 45620 01
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0.00000-01 1.00000 00 4.51430 00 7 02810 00 1 00000 00-2 73140 00 0 00000-01
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6.45580-01-4.01800-01 2.92680 00-9 87610 00 6 12000-01-5 96460-02 1 34450 00
-4.30850 00 6.13870-01 7 70290-02 7.90330-01-9.47810 00 6 22320-01 1 09960-01
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6.00880-01 4.16670 00 3.52520 02 6.89090-01 8 72260-01 1 44460 01-3 95810 02
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2.38230 03 7.94000-01 1.92390 00 6.54690 01-1 04570 03 1 00000 00

```

TABLE 3

CONTENTS OF RETRIEVAL FILE WITH HEADING

(Sheet 1 of 7)

VERIFICATION OF DATA TABLE

RETRIEVAL FILE NO ML3-05-1
 FILE SIZE = 17
 L/D = 0.5000
 ALFA = 1.1250

ECC RATIO CONSTANT EXPONENT
 NEAR FIELD 1.000100000 00 1.000000000 00
 FAR FIELD 1.000000000 00 0.000000000-01

POINT	LOAD	TAU	COMPARISON FCN	DERIVATIVE 1	DERIVATIVE 2	DERIVATIVE 3
1	0.000000000-01	0.000000000-01	1.000000000 00	-1.650200000 00	0.000000000-01	1.980300000 02
2	5.624343611D-02	3.576800000-02	9.424900000-01	-1.523600000 00	7.083000000 00	-1.329300000 02
3	9.208140634D-02	5.845600000-02	9.094800000-01	-1.397100000 00	4.067100000 00	-6.644800000 01
4	1.265496138D-01	8.013800000-02	8.800300000-01	-1.324500000 00	2.626400000 00	1.206000000 01
5	2.024746314D-01	1.271800000-01	8.208500000-01	-1.187600000 00	3.193700000 00	1.386800000-02
6	3.374875818D-01	2.072100000-01	7.360200000-01	-9.319700000-01	3.194800000 00	-1.726500000 00
7	4.921663392D-01	2.860200000-01	6.723600000-01	-6.855700000-01	3.058700000 00	-3.446500000 00
8	8.438904501D-01	4.462300000-01	5.994200000-01	-2.397700000-01	2.506600000 00	6.895900000-01
9	1.265506517D 00	5.742700000-01	5.895000000-01	8.683300000-02	2.594900000 00	5.207100000 00
10	1.687457536D 00	6.594300000-01	6.068500000-01	3.267100000-01	3.038300000 00	1.065900000 01
11	2.531635214D 00	7.605100000-01	6.572200000-01	6.882600000-01	4.115700000 00	2.439600000 01
12	3.375034900D 00	8.166200000-01	7.030300000-01	9.575700000-01	5.484500000 00	2.601500000 01
13	4.046930393D 00	8.457800000-01	7.334000000-01	1.128600000 00	6.243200000 00	3.497100000 01
14	5.060566484D 00	8.758000000-01	7.702600000-01	1.331800000 00	7.293100000 00	6.286900000 01
15	6.752413676D 00	9.064000000-01	8.147100000-01	1.584300000 00	9.216500000 00	3.488300000 01
16	1.013521696D 01	9.373900000-01	8.684100000-01	1.886700000 00	1.029800000 01	-1.644600000 02
17	INFINITE	1.000000000 00	1.000000000 00			

Table 3 - Contents of Retrieval File . . . (continued)

ATT	ANGLE	CONSTANT	EXPONENT
NEAR	FIELD	9 0000000000 01 0 0000000000-01	
FAR	FIELD	1 0007000000 02 -5 0000000000-01	

POINT	LOAD	TAU	COMPARISON FCN	DERIVATIVE 1	DERIVATIVE 2	DERIVATIVE 3
1	0.0000000000-01	0.0000000000-01	1.0000000000 00	-2 2698000000 00	0.0000000000-01	5.0412000000 02
2	5 6243436110-02	3 5768000000-02	9 2266000000-01	-1 9473000000 00	1 8031000000 01	-4 9054000000 02
3	9 2081406340-02	5 8456000000-02	8 8216000000-01	-1 6645000000 00	6 9020000000 00	4 2378000000 01
4	1 2654961380-01	8 0130000000-02	3 4777000000-01	-1 5049000000 00	7 8208000000 00	-4 8412000000 01
5	2 0247463140-01	1 2718000000-01	7 8479000000-01	-1 1905000000 00	5 5436000000 00	-2 1033000000 01
6	3 3748758180-01	2 0721000000-01	7 0546000000-01	-8 1422000000-01	3 8601000000 00	-1 5182000000 01
7	4 8216633920-01	2 8602000000-01	6 5205000000-01	-5 5717000000-01	2 6638000000 00	-6 8634000000 00
8	8 4789204501D-01	4 4623000000-01	5 9227000000-01	-2 1849000000-01	1 5642000000 00	9 3216000000-01
9	1 2655065170 00	5 7427000000-01	5 7744000000-01	-1 0573000000-02	1 6835000000 00	4 1808000000 00
10	1 6874575560 00	6 5943000000-01	5 8307000000-01	1 4796000000-01	2 0396000000 00	1 5715000000 01
11	2 5316352140 00	7 6051000000-01	6 1115000000-01	4 3440000000-01	3 6280000000 00	4 4005000000 01
12	3 3750349000 00	8 1662000000-01	6 4253000000-01	7 0720000000-01	6 0969000000 00	5 9916000000 01
13	4 0469303930 00	8 4578000000-01	6 6600000000-01	9 1050000000-01	7 9443000000 00	1 3540000000 02
14	5 0605664840 00	8 7580000000-01	6 9748000000-01	1 2070000000 00	1 1909000000 01	1 6682000000 02
15	6 7524136760 00	9 0640000000-01	7 4078000000-01	1 6494000000 00	1 7013000000 01	5 4840000000 02
16	1 0135216960 01	9 3739000000-01	8 0278000000-01	2 4400000000 00	3 4008000000 01	-5 4315000000 02
17	INFINITE	1 0000000000 00	1 0000000000 00			

TORQUE	NEAR	FIELD	1 6463000000 01 0 0000000000-01
	FAR	FIELD	1 7306000000 01 5 0000000000-01

POINT	LOAD	TAU	COMPARISON FCN	DERIVATIVE 1	DERIVATIVE 2	DERIVATIVE 3
1	0.0000000000-01	0.0000000000-01	1.0000000000 00	1 2603000000 00	0 0000000000-01	-3 1207000000 02
2	5 6243436110-02	3 5768000000-02	1 0427000000 00	1 0607000000 00	-1 1162000000 01	3 5255000000 02
3	9 2081406340-02	5 8456000000-02	1 0646000000 00	8 9819000000-01	-3 1636000000 00	-1 9538000000 01
4	1 2654961380-01	8 0138000000-02	1 0833000000 00	8 2500000000-01	-3 5872000000 00	2 1639000000 01
5	2 0247463140-01	1 2718000000-01	1 1185000000 00	6 8020000000-01	-2 5694000000 00	7 0205000000 00
6	3 3748758180-01	2 0721000000-01	1 1653000000 00	4 9704000000-01	-2 0075000000 00	5 1224000000 00
7	4 8216633920-01	2 8602000000-01	1 1987000000 00	3 5475000000-01	-1 6038000000 00	-9 9900000000-01
8	8 4389045010-01	4 4623000000-01	1 2342000000 00	8 4981000000-02	-1 7639000000 00	-9 9638000000-01
9	1 2655065170 00	5 7427000000-01	1 2303000000 00	-1 4904000000-01	-1 8914000000 00	-3 7706000000 00
10	1 6874575560 00	6 5943000000-01	1 1651000000 00	-5 8304000000-01	-2 2126000000 00	-6 9700000000 00
11	2 5316352140 00	7 6051000000-01	1 1280000000 00	-7 3778000000-01	-2 5991000000 00	4 7046000000 01
12	3 3750349000 00	8 1662000000-01	1 1056000000 00	-7 9358000000-01	-1 2270000000 00	-9 1263000000 01
13	4 0469303930 00	8 4578000000-01	1 0808000000 00	-8 7155000000-01	-3 9670000000 00	4 5428000000 02
14	5 0605664840 00	8 7580000000-01	1 0340000000 00	-7 8032000000-01	9 9308000000 00	-2 4352000000 02
15	6 7524136760 00	9 0640000000-01	1 0338000000 00	-5 8950000000-01	2 3839000000 00	-3 8074000000 01
16	1 0135216960 01	9 3739000000-01	1 0000000000 00			
17	INFINITE	1 0000000000 00	1 0000000000 00			

(Sheet 2 of 7)

Table 3 - Contents of Retrieval File . . . (continued)

REQ FLOW	LOAD	CONSTANT	EXPONENT
NEAR FIELD	4.713300000 00	0.000000000-01	
FAR FIELD	4.071100000 00	0.000000000-01	

POINT	LOAD	TAU	COMPARISON FCN	DERIVATIVE 1	DERIVATIVE 2	DERIVATIVE 3
1	0.000000000-01	0.000000000-01	1.000000000 00	7.728600000-02	0.000000000-01	-2.951100000 01
2	5.624343611D-02	3.576800000-02	1.002500000 00	5.840900000-02	-1.055500000 00	1.054000000 01
3	9.208140634D-02	5.845600000-02	1.003600000 00	3.717300000-02	-8.164000000-01	2.643400000 01
4	1.265496138D-01	8.013800000-02	1.004300000 00	2.568600000-02	-2.432300000-01	-2.224500000 00
5	2.024746314D-01	1.271800000-01	1.005200000 00	1.178300000-02	-3.478700000-01	2.511400000 00
6	3.374875818D-01	2.072100000-01	1.005200000 00	-8.015600000-03	-1.468700000-01	2.750700000 00
7	4.821563392D-01	2.860200000-01	1.004400000 00	-1.104800000-02	6.989800000-02	-2.535700000-01
8	8.438904501D-01	4.462300000-01	1.003300000 00	-3.104200000-03	2.927400000-02	4.733600000-01
9	1.265506517D 00	5.742700000-01	1.003300000 00	4.524400000-03	8.988400000-02	-9.168100000-01
10	1.687457556D 00	6.594300000-01	1.003900000 00	8.854500000-03	1.180400000-02	3.866500000-01
11	2.531635214D 00	7.605100000-01	1.005000000 00	1.202300000-02	5.088600000-02	3.543500000-01
12	3.375034900D 00	8.166200000-01	1.005700000 00	1.543500000-02	7.076600000-02	-2.067600000 01
13	4.046930393D 00	8.457800000-01	1.006100000 00	8.706100000-02	-5.322400000-01	1.729400000 01
14	5.060566484D 00	8.758000000-01	1.006200000 00	5.208000000-04	-1.302500000-02	-3.916200000 01
15	6.752413676D 00	9.064000000-01	1.006000000 00	-1.820400000-02	-1.211100000 00	2.420300000 00
16	1.013521696D 01	9.373900000-01	1.004900000 00	-5.457400000-02	-1.136100000 00	1.814500000 01
17	INFINITE	1.000000000 00	1.000000000 00			

FLOW LOSS	CONSTANT	EXPONENT
NEAR FIELD	1.490200000 00	1.000000000 00
FAR FIELD	1.617000000 00	0.000000000-01

POINT	LOAD	TAU	COMPARISON FCN	DERIVATIVE 1	DERIVATIVE 2	DERIVATIVE 3
1	0.000000000-01	0.000000000-01	1.000000000 00	-1.548000000 00	0.000000000-01	1.275300000 02
2	5.624343611D-02	3.576800000-02	9.456000000-01	-1.466500000 00	4.561600000 00	-1.186700000 02
3	9.208140634D-02	5.845600000-02	9.132700000-01	-1.393500000 00	1.869100000 00	7.361700000 01
4	1.265496138D-01	8.013800000-02	8.836200000-01	-1.335700000 00	3.465300000 00	-1.620300000 01
5	2.024746314D-01	1.271800000-01	8.243500000-01	-1.190600000 00	2.703200000 00	7.356600000 00
6	3.374875818D-01	2.072100000-01	7.383600000-01	-9.500400000-01	3.308000000 00	-4.652700000 00
7	4.821663392D-01	2.860200000-01	6.733900000-01	-7.038100000-01	2.941300000 00	-2.416700000 00
8	8.438904501D-01	4.462300000-01	5.967200000-01	-2.636000000-01	2.554100000 00	7.022000000-01
9	1.265506517D 00	5.742700000-01	5.841500000-01	6.919600000-02	2.644100000 00	4.600700000 00
10	1.687457556D 00	6.594300000-01	6.001100000-01	3.110600000-01	3.035900000 00	1.136200000 01
11	2.531635214D 00	7.605100000-01	6.490100000-01	6.759600000-01	4.184300000 00	3.121100000 01
12	3.375034900D 00	8.166200000-01	6.944400000-01	9.598400000-01	5.935400000 00	-7.642800000 00
13	4.046930393D 00	8.457800000-01	7.249300000-01	1.129700000 00	5.712300000 00	5.447800000 01
14	5.060566484D 00	8.758000000-01	7.616600000-01	1.325700000 00	7.346700000 00	1.225500000 01
15	6.752413676D 00	9.064000000-01	8.057200000-01	1.556200000 00	7.721600000 00	2.626000000 02
16	1.013521696D 01	9.373900000-01	8.589600000-01	1.921600000 00	1.586600000 01	-2.533000000 02
17	INFINITE	1.000000000 00	1.000000000 00			

(Sheet 3 of 7)

Table 3 - Contents of Retrieval File . . . (continued)

K-XX	CONSTANT		EXPONENT		COMPARISON FCN		TAU		DERIVATIVE 1		DERIVATIVE 2		DERIVATIVE 3	
	NEAR FIELD	-5.5102000000-01	1.0000000000 00		LOAD	0.0000000000-01	-1.0000000000 00	2.4323000000 00	0.0000000000-01	0.0000000000-01	0.0000000000-01	7.1487000000 02	02	
	FAR FIELD	9.0173000000-01	2.5000000000 00			3.5768000000-02	-9.0755000000-01	2.9896000000 00	2.5569000000 01	-9.1419000000 02	02	02		
1						5.624343611D-02	3.5768000000-02	2.9896000000 00	2.5569000000 01	-9.1419000000 02	02	02		
2						9.208140634D-02	5.8456000000-02	3.2344000000 00	4.8283000000 00	5.0437000000 02	02	02		
3						1.265496138D-01	8.0138000000-02	3.4576000000 00	1.5764000000 01	-2.2806000000 02	02	02		
4						2.024746314D-01	1.2718000000-01	3.9469000000 00	5.0357000000 00	-2.7454000000 00	00	00		
5						3.374875818D-01	2.0721000000-01	4.3411000000 00	4.8160000000 00	-2.0724000000 02	02	02		
6						4.821663392D-01	2.8602000000-01	4.0770000000 00	-1.1517000000 01	5.9633000000 01	5.9633000000 01	01	01	
7						8.438904501D-01	4.4623000000-01	2.9972000000 00	-1.9630000000 00	-1.1046000000 02	-1.1046000000 02	02	02	
8						1.265506517D 00	5.7427000000-01	1.8404000000 00	-1.6106000000 01	1.0971000000 02	1.0971000000 02	02	02	
9						1.687457556D 00	6.5943000000-01	8.6662000000-01	-6.7639000000 00	-6.0643000000 00	-6.0643000000 00	00	00	
10						2.531635214D 00	7.6051000000-01	1.5194000000-01	-7.3769000000 00	-4.4883000000-01	-4.4883000000-01	01	01	
11						3.375034900D 00	8.1462000000-01	-2.6268000000-01	-7.4020000000 00	-4.8558000000 02	-4.8558000000 02	02	02	
12						4.046930393D 00	8.4578000000-01	-2.7207000000-01	6.7576000000 00	-6.3813000000 02	-6.3813000000 02	02	02	
13						5.060566484D 00	8.7580000000-01	-3.5675000000-01	-1.2399000000 01	3.6049000000 02	3.6049000000 02	02	02	
14						6.752413676D 00	9.0640000000-01	-5.6738000000-01	-1.3678000000 00	-3.5481000000 02	-3.5481000000 02	02	02	
15						1.013521696D 01	9.3739000000-01	-7.8015000000-01	-1.2363000000 01	1.9747000000 02	1.9747000000 02	02	02	
16						INFINITE	1.0000000000 00							
17														

B-XX	CONSTANT		EXPONENT		COMPARISON FCN		TAU		DERIVATIVE 1		DERIVATIVE 2		DERIVATIVE 3	
	NEAR FIELD	2.0058000000 00	0.0000000000-01		LOAD	0.0000000000-01	1.0000000000 00	-1.8609000000 00	0.0000000000-01	0.0000000000-01	0.0000000000-01	-9.6880000000 02	02	
	FAR FIELD	1.4450000000 01	1.5000000000 00			3.5768000000-02	9.2605000000-01	-2.4806000000 00	-3.4652000000 01	2.2807000000 03	03	03		
1						5.624343611D-02	3.5768000000-02	9.2605000000-01	-2.4806000000 00	-3.4652000000 01	2.2807000000 03	03	03	
2						9.208140634D-02	5.8456000000-02	8.6529000000-01	-2.6798000000 00	1.7092000000 01	1.7092000000 01	-1.9040000000 02	02	
3						1.265496138D-01	8.0138000000-02	8.1088000000-01	-2.3540000000 00	1.2964000000 01	1.2964000000 01	2.1440000000 01	01	
4						2.024746314D-01	1.2718000000-01	7.1486000000-01	-1.7204000000 00	1.3973000000 01	1.3973000000 01	-7.1428000000 01	01	
5						3.374875818D-01	2.0721000000-01	6.1582000000-01	-8.3091000000-01	8.2564000000 00	8.2564000000 00	-7.3256000000 01	01	
6						4.821663392D-01	2.8602000000-01	5.7000000000-01	-4.0772000000-01	2.4831000000 00	2.4831000000 00	-1.1667000000 01	01	
7						8.438904501D-01	4.4623000000-01	5.2855000000-01	-1.5964000000-01	6.1388000000-01	6.1388000000-01	1.0713000000 01	01	
8						1.265506517D 00	5.7427000000-01	5.1689000000-01	6.7780000000-03	1.9855000000 00	1.9855000000 00	-1.7847000000 01	01	
9						1.687457556D 00	6.5943000000-01	5.2283000000-01	1.1115000000-01	4.6571000000-01	4.6571000000-01	3.7505000000 01	01	
10						2.531635214D 00	7.6051000000-01	5.4290000000-01	3.4982000000-01	4.2567000000 00	4.2567000000 00	-4.0585000000 00	00	
11						3.375034900D 00	8.1462000000-01	5.6911000000-01	5.8228000000-01	4.0290000000 00	4.0290000000 00	5.2698000000 02	02	
12						4.046930393D 00	8.4578000000-01	9.2381000000-01	1.9396000000 01	1.9396000000 01	1.9396000000 01	1.2142000000 02	02	
13						5.060566484D 00	8.7580000000-01	6.2700000000-01	1.5608000000 00	2.3041000000 01	2.3041000000 01	3.0426000000 02	02	
14						6.752413676D 00	9.0640000000-01	6.8700000000-01	2.4083000000 00	3.2351000000 01	3.2351000000 01	-4.3686000000 02	02	
15						1.013521696D 01	9.3739000000-01	7.7500000000-01	3.2011000000 00	1.8813000000 01	1.8813000000 01	-3.0047000000 02	02	
16						INFINITE	1.0000000000 00							
17														

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Table 3 - Contents of Retrieval File . . . (continued)

K-X'

K-X	CONSTANT		TAU	EXPONENT		COMPARISON FCH	DERIVATIVE 1	DERIVATIVE 2	DERIVATIVE 3
	NEAR FIELD	1.0028000000 00 0.0000000000-01		FAR FIELD	2.4336000000 00 2.0000000000 00				
POINT	LOAD								
1	0.0000000000-01	0.0000000000-01	0.0000000000-01	1.0000000000 00	2.5245000000-01	0.0000000000-01	6.9107000000 02		
2	5.624343611D-02	3.5768000000-02	3.5768000000-02	1.0143000000 00	6.9450000000-01	2.4718000000-01	-3.6921000000 02		
3	9.208140634D-02	5.8456000000-02	5.8456000000-02	1.0357000000 00	1.1603000000 00	1.6341000000 01	-1.1674000000 02		
4	1.265496138D-01	8.0138000000-02	8.0138000000-02	1.0645000000 00	1.4872000000 00	1.3810000000 01	-1.4059000000 02		
5	2.024746314D-01	1.2718000000-01	1.2718000000-01	1.1473000000 00	1.9813000000 00	7.1964000000 00	-1.6511000000 02		
6	3.374875818D-01	2.0721000000-01	2.0721000000-01	1.3148000000 00	2.0284000000 00	-6.0173000000 00	-7.0334000000 00		
7	4.821663392D-01	2.8602000000-01	2.8602000000-01	1.4554000000 00	1.5324000000 00	-6.5716000000 00	-2.4457000000 01		
8	8.438904501D-01	4.4623000000-01	4.4623000000-01	1.5998000000 00	1.6564000000-01	-1.0490000000 01	3.9955000000 01		
9	1.265506517D 00	5.7427000000-01	5.7427000000-01	1.5490000000 00	-8.4997000000-01	-5.3741000000 00	1.6620000000 00		
10	1.687452556D 00	6.5943000000-01	6.5943000000-01	1.4573000000 00	-1.3016000000 00	-5.2326000000 00	5.4599000000 01		
11	2.531635214D 00	7.6051000000-01	7.6051000000-01	1.3084000000 00	-1.5516000000 00	2.8626000000-01	-3.7039000000 01		
12	3.375034900D 00	8.1662000000-01	8.1662000000-01	1.2207000000 00	-1.5938000000 00	-1.7920000000 00	8.1851000000 01		
13	4.046930393D 00	8.4578000000-01	8.4578000000-01	1.1738000000 00	-1.6113000000 00	5.9479000000-01	2.8899000000 02		
14	5.060566484D 00	8.7580000000-01	8.7580000000-01	1.1270000000 00	-1.4632000000 00	9.2704000000 00	-1.1846000000 02		
15	6.752413676D 00	9.0640000000-01	9.0640000000-01	1.0860000000 00	-1.2350000000 00	5.6455000000 00	1.1328000000 02		
16	1.013521696D 01	9.3739000000-01	9.3739000000-01	1.0510000000 00	-1.0057000000 00	9.1561000000 00	-1.4624000000 02		
17	INFINITE	1.0000000000 00	1.0000000000 00	1.0000000000 00					

B-XY

B-XY	CONSTANT		EXPONENT		COMPARISON FCH	DERIVATIVE 1	DERIVATIVE 2	DERIVATIVE 3
NEAR FIELD	5.096000000 00	1.000000000 00	FAR FIELD	4.376500000 00				
POINT	LOAD	TAU						
1	0.000000000D-01	0.000000000D-01	1.000000000 00	1.000000000D-01	5.062200000D-01	0.000000000D-01	0.000000000D-01	2.482800000 02
2	5.624343611D-02	3.576800000D-02	1.020000000 00	1.020000000D-02	6.650400000D-01	8.880400000D-01	8.880400000D-01	-6.031100000 02
3	9.208140634D-02	5.845600000D-02	1.036200000 00	1.036200000D-02	7.112900000D-01	-4.803000000D-01	-4.803000000D-01	2.983200000 02
4	1.265496138D-01	8.013800000D-02	1.051000000 00	1.051000000D-02	6.772700000D-01	1.665200000D-01	1.665200000D-01	-4.626700000 01
5	2.024746314D-01	1.271800000D-01	1.083900000 00	1.083900000D-01	7.044100000D-01	-5.112900000D-01	-5.112900000D-01	2.150100000 01
6	3.374875818D-01	2.072100000D-01	1.136800000 00	1.136800000D-01	5.946400000D-01	-2.232000000D-01	-2.232000000D-01	3.286600000 00
7	4.821663392D-01	2.860200000D-01	1.177000000 00	1.177000000D-01	4.289400000D-01	-1.973000000D-01	-1.973000000D-01	-5.981000000 00
8	8.438904501D-01	4.462300000D-01	1.216300000 00	1.216300000D-01	3.608200000D-02	-2.931200000D-02	-2.931200000D-02	6.024900000 00
9	1.265506517D 00	5.742700000D-01	1.199000000 00	1.199000000D-01	-2.898500000D-01	-2.159800000D-01	-2.159800000D-01	2.249200000 01
10	1.687457556D 00	6.594300000D-01	1.168800000 00	1.168800000D-01	-3.922200000D-01	-2.444000000D-01	-2.444000000D-01	5.464800000D-01
11	2.531635214D 00	7.605100000D-01	1.128000000 00	1.128000000D-01	-4.141300000D-01	-1.891600000D-01	-1.891600000D-01	-2.939000000 01
12	3.375034900D 00	8.166200000D-01	1.103600000 00	1.103600000D-01	-4.710100000D-01	-1.838200000D-01	-1.838200000D-01	1.007100000 02
13	4.046930393D 00	8.457800000D-01	1.089500000 00	1.089500000D-01	-4.817900000D-01	1.098600000D-01	1.098600000D-01	-3.396600000 02
14	5.060566484D 00	8.758000000D-01	1.074000000 00	1.074000000D-01	-6.018700000D-01	-9.098000000D-01	-9.098000000D-01	5.605000000 02
15	6.752413676D 00	9.064000000D-01	1.054000000 00	1.054000000D-01	-6.178500000D-01	8.053300000D-01	8.053300000D-01	-3.467400000 02
16	1.013521696D 01	9.373900000D-01	1.037000000 00	1.037000000D-01	-5.347800000D-01	-2.692000000D-01	-2.692000000D-01	4.299700000 01
17	INFINITE	1.000000000D 00	1.000000000 00	1.000000000D 00				(Sheet 5 of 7)

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Table 3 - Contents of Retrieval File . . . (continued)

K-YK	CONSTANT	EXPONENT	COMPARISON FCN	DERIVATIVE 1	DERIVATIVE 2	DERIVATIVE 3
NEAR FIELD	-2.279900000D 00	0.000000000D -01				
FAR FIELD	2.246000000D -01	2.500000000D 00				
POINT	LOAD	TAU	COMPARISON FCN	DERIVATIVE 1	DERIVATIVE 2	DERIVATIVE 3
1	0.000000000D -01	0.000000000D -01	-1.000000000D 00	8.051300000D -01	0.000000000D -01	-3.235700000D 02
2	5.624343611D -02	3.576800000D -02	-9.736700000D -01	5.981500000D -01	-1.157300000D 01	-1.706300000D 02
3	9.208140634D -02	5.845600000D -02	-9.634100000D -01	2.916600000D -01	-1.544500000D 01	1.428400000D 03
4	1.265496138D -01	8.013800000D -02	-9.582900000D -01	2.925400000D -01	1.552600000D 01	-6.040900000D 02
5	2.024746314D -01	1.271800000D -01	-9.378300000D -01	3.545100000D -01	-1.289200000D 01	2.330800000D 02
6	3.374975818D -01	2.072100000D -01	-9.308300000D -01	6.923100000D -02	5.762200000D 00	-1.044400000D 02
7	4.821663392D -01	2.860200000D -01	-9.160000000D -01	1.930000000D -01	-2.468900000D 00	9.528200000D 01
8	8.438904501D -01	4.462300000D -01	-8.505000000D -01	1.026300000D 00	1.279600000D 01	-2.465800000D 01
9	1.265506517D 00	5.742700000D -01	-6.228300000D -01	2.462600000D 00	9.639100000D 00	2.291200000D 02
10	1.687457556D 00	6.594300000D -01	-3.545800000D -01	4.114300000D 00	2.915100000D 01	-8.580900000D 01
11	2.531635214D 00	7.605100000D -01	1.954400000D -01	6.622500000D 00	2.047700000D 01	1.086100000D 02
12	3.375034900D 00	8.166200000D -01	6.024600000D -01	7.942400000D 00	2.657200000D 01	-7.573800000D 03
13	4.046930393D 00	8.457800000D -01	8.140600000D -01	5.437200000D 00	-1.942800000D 02	5.201900000D 03
14	5.060566434D 00	8.758000000D -01	9.150000000D -01	2.008900000D 00	-3.811900000D 01	2.875700000D 02
15	6.752413676D 00	9.064000000D -01	9.600000000D -01	9.771200000D -01	-2.931900000D 01	7.656100000D 02
16	1.013521696D 01	9.373900000D -01	9.800000000D -01	4.361600000D -01	-5.592900000D 00	8.932900000D 01
17	INFINITE	1.000000000D 00	1.000000000D 00			
B-YK	CONSTANT	EXPONENT	COMPARISON FCN	DERIVATIVE 1	DERIVATIVE 2	DERIVATIVE 3
NEAR FIELD	5.096000000D 00	1.000000000D 00				
FAR FIELD	4.376500000D 00	1.500000000D 00				
POINT	LOAD	TAU	COMPARISON FCN	DERIVATIVE 1	DERIVATIVE 2	DERIVATIVE 3
1	0.000000000D -01	0.000000000D -01	1.000000000D 00	5.062200000D -01	0.000000000D -01	2.482800000D 02
2	5.624343611D -02	3.576800000D -02	1.020000000D 00	6.650400000D -01	8.880400000D 00	-6.031100000D 02
3	9.208140634D -02	5.845600000D -02	1.036200000D 00	7.112900000D -01	-4.803000000D 00	2.983200000D 02
4	1.265496138D -01	8.013800000D -02	1.051000000D 00	6.772700000D -01	1.665200000D 00	-4.626700000D 01
5	2.024746314D -01	1.271800000D -01	1.083900000D 00	7.044100000D -01	-5.112900000D -01	-2.150100000D 01
6	3.374975818D -01	2.072100000D -01	1.136800000D 00	5.946400000D -01	-2.232000000D 00	3.286600000D 00
7	4.821663392D -01	2.860200000D -01	1.177000000D 00	4.289400000D -01	-1.973000000D 00	-5.981000000D 00
8	8.438904501D -01	4.462300000D -01	1.216300000D 00	3.608200000D -02	-2.931200000D 00	6.024900000D 00
9	1.265506517D 00	5.742700000D -01	1.199000000D 00	-2.898500000D -01	-2.159800000D 00	2.249200000D 01
10	1.687457556D 00	6.594300000D -01	1.168800000D 00	-3.922200000D -01	-2.440000000D -01	5.464800000D -01
11	2.531635214D 00	7.605100000D -01	1.128000000D 00	-4.141300000D -01	-1.891600000D -01	-2.939000000D 01
12	3.375034900D 00	8.166200000D -01	1.103600000D 00	-4.710100000D -01	-1.838200000D 00	1.007100000D 02
13	4.046930393D 00	8.457800000D -01	1.089500000D 00	-4.817900000D -01	1.098600000D 00	-3.396600000D 02
14	5.060566434D 00	8.758000000D -01	1.074000000D 00	-6.018700000D -01	9.098000000D 00	5.605000000D 02
15	6.752413676D 00	9.064000000D -01	1.054000000D 00	-6.178500000D -01	8.053300000D 00	-3.467400000D 02
16	1.013521696D 01	9.373900000D -01	1.037000000D 00	-5.347800000D -01	-2.692000000D 00	4.299700000D 01
17	INFINITE	1.000000000D 00	1.000000000D 00			

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Table 3 - Contents of Retrieval File . . . (continued)

K-YY	NEAR FIELD	FAR FIELD	CONSTANT	EXPONENT		
	4.720300000 00	1.000000000 00				
	3.400700000 00	1.500000000 00				
POINT	LOAD	TAU	COMPARISON FCN	DERIVATIVE 1	DERIVATIVE 2	DERIVATIVE 3
1	0.000000000D-01	0.000000000D-01	1.000000000 00	5.962500000D-01	0.000000000D-01	1.145300000D 02
2	5.624343611D-02	3.576900000D-02	1.022200000 00	6.695100000D-01	4.009650000D 00	-7.933000000D 02
3	9.208140634D-02	5.845600000D-02	1.036900000 00	5.582700000D-01	-1.390200000D 01	7.435900000D 02
4	1.265496138D-01	8.013800000D-02	1.047000000 00	4.316400000D-01	2.220500000D 00	-1.303700000D 02
5	2.024746314D-01	1.271800000D-01	1.067500000 00	3.918400000D-01	-3.912300000D 00	2.891000000D 01
6	3.374875818D-01	2.072100000D-01	1.088800000 00	1.713200000D-01	-1.598700000D 00	8.128000000D 00
7	4.821663392D-01	2.860200000D-01	1.098000000 00	7.056800000D-02	-9.581100000D-01	-7.309600000D 00
8	8.438904501D-01	4.462300000D-01	1.092000000 00	-1.767400000D-01	-2.129200000D 00	2.224600000D 01
9	1.265506517D 00	5.742700000D-01	1.059700000 00	-2.670100000D-01	7.192100000D-01	-5.993900000D 01
10	1.687457556D 00	6.594300000D-01	1.033400000 00	-4.231000000D-01	-4.385200000D 00	6.837800000D 01
11	2.531635214D 00	7.605100000D-01	9.800000000D-01	-5.170500000D-01	2.526500000D 00	-6.846100000D 01
12	3.375034900D 00	8.166200000D-01	9.529500000D-01	-4.830500000D-01	-1.314900000D 00	4.464400000D 02
13	4.046930393D 00	8.457800000D-01	9.401500000D-01	-3.315900000D-01	1.170300000D 01	-3.258200000D 02
14	5.060566484D 00	8.758000000D-01	9.340000000D-01	-1.270700000D-01	1.922100000D 00	4.164200000D 02
15	6.752413676D 00	9.064000000D-01	9.330000000D-01	1.267000000D-01	1.466400000D 01	6.410600000D 00
16	1.013521696D 01	9.373900000D-01	9.440000000D-01	5.842300000D-01	1.486300000D 01	-2.373900000D 02
17	INFINITE	1.000000000D 00	1.000000000D 00			
B-YY	NEAR FIELD	FAR FIELD	CONSTANT	EXPONENT		
	4.514300000 00	0.000000000D-01				
	7.028100000 00	1.000000000 00				
POINT	LOAD	TAU	COMPARISON FCN	DERIVATIVE 1	DERIVATIVE 2	DERIVATIVE 3
1	0.000000000D-01	0.000000000D-01	1.000000000 00	-2.731400000D 00	0.000000000D-01	6.696000000D 02
2	5.624343611D-02	3.576900000D-02	9.074100000D-01	-2.303100000D 00	2.395000000D 01	-4.634200000D 02
3	9.208140634D-02	5.845600000D-02	8.604200000D-01	-1.879000000D 00	1.343600000D 01	-1.522500000D 02
4	1.265496138D-01	8.013800000D-02	8.225800000D-01	-1.623400000D 00	1.013500000D 01	-1.990800000D 01
5	2.024746314D-01	1.271800000D-01	7.570900000D-01	-1.168700000D 00	9.198700000D 00	-7.034600000D 01
6	3.374875818D-01	2.072100000D-01	6.870000000D-01	-6.577700000D-01	3.569000000D 00	-8.148200000D 00
7	4.821663392D-01	2.860200000D-01	6.455800000D-01	-4.018000000D-01	2.926800000D 00	-9.876100000D 00
8	8.438904501D-01	4.462300000D-01	6.120000000D-01	-5.964600000D-02	1.344500000D 00	-4.328500000D 00
9	1.265506517D 00	5.742700000D-01	6.138700000D-01	7.702900000D-02	7.903300000D-01	-9.478100000D 00
10	1.687457556D 00	6.594300000D-01	6.223200000D-01	1.099600000D-01	-1.692000000D-02	4.735300000D 01
11	2.531635214D 00	7.605100000D-01	6.415000000D-01	3.501700000D-01	4.769600000D 00	-1.074500000D 01
12	3.375034900D 00	8.166200000D-01	6.893400000D-01	6.008800000D-01	1.667000000D 00	3.525200000D 02
13	4.046930393D 00	8.457800000D-01	6.890900000D-01	8.722600000D-01	1.444600000D 01	-3.958100000D 02
14	5.060566484D 00	8.758000000D-01	7.200000000D-01	1.127600000D 00	2.564100000D 00	-3.569500000D 02
15	6.752413676D 00	9.064000000D-01	7.540000000D-01	1.038900000D 00	-8.358400000D 00	2.382300000D 03
16	1.013521696D 01	9.373900000D-01	7.940000000D-01	1.923900000D 00	6.546900000D 01	-1.045700000D 03
17	INFINITE	1.000000000D 00	1.000000000D 00			

(Sheet 7 of 7)

SECTION IV

FOUNDATIONS OF THE STORAGE RETRIEVAL METHOD

4.1 Choice of the Operating Parameter

The state of static equilibrium of a fluid film journal bearing may be specified either in terms of a static load vector or a static displacement vector. Traditionally, the bearing designer tends to work with the displacement vector not only because the eccentricity ratio is an easy to use design parameter in bearing analysis but also because the bearing designer is concerned with the minimum film thickness which is directly related to the eccentricity ratio. A rotor dynamicist, on the other hand, starts with a known bearing design. Furthermore, the static load condition is usually known.* Therefore; the load parameter, as readily computed according to Eq. (2), is the natural choice to define the data point in the table.

The complete range of the load parameter should span from zero to infinity. Obviously it is not possible to treat unbounded numbers in a data table. As a practical matter, some arbitrary cutoff point is accepted when a table is being prepared. At the time of data retrieval, if the requested data point should lie outside the available data range, a judicial extrapolation procedure must be used. The most commonly used extrapolation procedure is the power law, which amounts to a straight line extension of a log-log plot. The desired retrieval method requires the inclusion of such an extrapolation procedure which also retains overall smoothness within the data range.

The graphical extrapolation process can be emulated by a computer program. The power law extrapolation for an infinitesimal load can be expressed as

*The new rotor dynamics software [9] has a feature to calculate the load vector of each bearing.

$$\bar{Z} = a\bar{W}^{s_1} \quad \text{for} \quad \bar{W} \ll 1 \quad (48)$$

Its log differential form is

$$\frac{d\bar{Z}}{\bar{Z}} = s_1 \frac{d\bar{W}}{\bar{W}}$$

Or,

$$s_1 = \frac{d\bar{Z}}{d\bar{W}} \frac{\bar{W}}{\bar{Z}} \quad \text{for} \quad \bar{W} \ll 1 \quad (49)$$

With the differentials replaced by finite differences and (\bar{W}, \bar{Z}) approximated by average values, Eq. (49) can be used to calculate s_1 from two data points corresponding to the smallest values of \bar{W} in the data table.

Similarly, the power law extrapolation for the load parameter tending to infinity is

$$\bar{Z} = b\bar{W}^{s_2} \quad \text{for} \quad \bar{W} \gg 1 \quad (50)$$

Or,

$$s_2 = \frac{d\bar{Z}}{d\bar{W}} \frac{\bar{W}}{\bar{Z}} \quad \text{for} \quad \bar{W} \gg 1 \quad (51)$$

s_2 can thus be calculated with the two data points which represent the largest values of \bar{W} in the data table.

The values of s_1 and s_2 as computed numerically can have either sign and certainly may not always be integers. As illustrated in the π -film short bearing analysis, the factor $(1-\epsilon^2)^{-1/2}$ shows up prominently in various coefficients. Therefore, the values of s_1 and s_2 are rounded off to the nearest half-integer.

Upon fixing s_1 and s_2 , the near-field and far-field data behavior can be more accurately represented by

$$\lim_{\bar{W} \rightarrow 0} \bar{Z} = \bar{W}^{s_1} \{a_0 + a_1 \bar{W} + a_2 \bar{W}^2\} \quad (52)$$

$$\lim_{\bar{W} \rightarrow \infty} \bar{Z} = \bar{W}^{s_1} \{b_0 + b_1 \bar{W}^{-1} + b_2 \bar{W}^{-2}\} \quad (53)$$

and the coefficients a_0 and b_0 , respectively, can be determined numerically from three consecutive data points in each end of the data table. The other coefficients (a_1, a_2, b_1, b_2) are not explicitly required to define the extreme field asymptotes which are

$$\lim_{\bar{W} \rightarrow 0} \bar{Z} = a_0 \bar{W}^{s_1}; \quad \lim_{\bar{W} \rightarrow \infty} \bar{Z} = b_0 \bar{W}^{s_2} \quad (54)$$

4.2 Full Range Interpolation

An important requirement for a foolproof full range interpolation procedure is to conform to the asymptotic properties uniformly in both the near field and in the far field. This very stringent requirement is satisfied by comparing the data point with a reference function \bar{Z}_0 which has the following properties:

$$(1) \quad \lim_{\bar{W} \rightarrow 0} \frac{|\bar{Z}|}{\bar{Z}_0} = 1 \quad (55)$$

$$(2) \quad \lim_{\bar{W} \rightarrow \infty} \frac{|\bar{Z}|}{\bar{Z}_0} = 1 \quad (56)$$

$$(3) \quad \bar{Z}_0 \quad (0 < \bar{W} < \infty) > 0 \quad \text{and is bounded.} \quad (57)$$

Many simple functions can be concocted to satisfy these conditions for a specific combination of s_1 and s_2 . After some experimentation, the reference function is chosen to have one of three forms depending on the relative values of s_1 and s_2 :

(a) $s_1 > s_2$ then

$$\bar{Z}_0 = \frac{|a_0 b_0| \bar{W}^{s_1 + s_2} (1 + \bar{W})}{|a_0| \bar{W}^{s_1 + 1} + |b_0| \bar{W}^{s_2}} \quad (58a)$$

(b) $s_2 - 1 < s_1 \leq s_2$ then

$$\bar{Z}_0 = \frac{|a_0| \bar{W}^{s_1} + |b_0| \bar{W}^{s_2 + 1}}{1 + \bar{W}} \quad (58b)$$

(c) $s_2 - 1 > s_1$ then

$$\bar{Z}_0 = |a_0| \bar{W}^{s_1} + |b_0| \bar{W}^{s_2} \quad (58c)$$

The interpolation operation is then to be performed on the comparison function, which is simply the ratio between the data point and the reference function at the same value of the load parameter; i.e.

$$\bar{Z}_c(\bar{W}) = \bar{Z}(W) / \bar{Z}_0(\bar{W}) \quad (59)$$

The near-field and far-field values of the comparison function are simply

$$\bar{Z}_c(W \rightarrow 0) = \text{sg}\{a_0\}; \quad \bar{Z}_c(W \rightarrow \infty) = \text{sg}\{b_0\} \quad (60)$$

\bar{Z}_c is bounded for all values of \bar{W} . Since \bar{Z}_0 is everywhere smooth, smooth-

ness, or the lack of it, in the data would be directly reflected by the comparison function. Because \bar{Z}_c has a limited range, its maximum magnitude is usually near unity; its smoothness can be readily verified. Examination of \bar{Z}_c is thus a very effective way to discover inaccuracy in the data table. Further discussion of this question will be pursued in Section 4.4.

Obtaining a $\bar{Z}_c(\bar{W})$ at discrete points of \bar{W} , interpolation can still be problematic if the desired value of \bar{W} exceeds the largest data point. This difficulty is overcome by mapping the semi-infinite range of the load parameter into a finite domain of a working parameter. To assure one-to-one transformation between the load parameter and the working parameter, a monotonic differential relationship is desired. The selected transformation is

$$\tau = \frac{2}{\pi} \tan^{-1}(\bar{W}) \quad (61)$$

The inverse transformation is

$$\bar{W} = \tan\left(\frac{\pi}{2} \tau\right) \quad (62)$$

Differentiation of Eq. (61) yields

$$\frac{d\tau}{d\bar{W}} = \frac{(2/\pi)}{1 + (\bar{W})^2} \quad (63)$$

which is always positive and bounded. One may again note the near-field and far-field asymptotes of Eq. (61)

$$\lim_{\bar{W} \rightarrow 0} \tau = \frac{2}{\pi} \bar{W} ; \quad \lim_{\bar{W} \rightarrow \infty} \tau = 1 - \frac{1}{(\pi/2)\bar{W}} \quad (64)$$

These simple relationships allow one to examine the data points in all ranges of \bar{W} .

With the aid of Eq. (62), the comparison function can now be described in the domain $0 \leq \tau \leq 1$. $\bar{Z}_c(\tau)$ is in fact assured to be bounded and smooth. Established numerical interpolation schemes can be readily implemented on it. The selected approach is the third order spline function [9], which represents $\bar{Z}_c(\tau_i \leq \tau \leq \tau_{i+1})$ as

$$\bar{Z}_c = \bar{Z}_c(\tau_i) + a_i(\tau - \tau_i) + \frac{1}{2} b_i(\tau - \tau_i)^2 + \frac{1}{6} c_i(\tau - \tau_i)^3$$

i spans 1 to N if the full range is divided into N intervals (which may not be uniform). There is some flexibility in the choice of the coefficients at each of the end points where one free condition can be specified. The common convention is to let the outboard second derivative vanish at each end; i.e.

$$b_1 = 0; \text{ and } b_N + (\tau_{N+1} - \tau_N)c_N = 0$$

Sometimes, if justified by other arguments, one can elect to null the first derivative at either end; i.e.,

$$a_1 = 0; \text{ or } a_N + (\tau_{N+1} - \tau_N)b_N + \frac{1}{2}(\tau_{N+1} - \tau_N)^2 c_N = 0$$

4.3 Correction for L/D Variation

The length to diameter ratio is a major configuration parameter in the design of a fluid film bearing. Typically, in industrial practice, it is in the range of 0.4 - 0.75; occasionally it may be less than 0.25. Unfortunately, there is no standardization of its value. If the data bank were to include a range of L/D , its total storage requirement would be very large indeed. It is, therefore, useful to develop an approach to correct any deviation in the value of (L/D) from that of an available data table.

The short bearing analysis described in Appendix B contains a scaling law which is applicable to the dimensionless load as well as the dimensionless dynamic coefficients:

$$\bar{W}; \quad \bar{K}_{xx}, \text{ etc.}; \quad \bar{B}_{xx}, \text{ etc.} \sim \left(\frac{L}{D}\right)^2 \quad (66)$$

For the plain journal bearing, Lund [12] showed that this scaling yields reasonable results even for $L/D = 1.0$ for modest eccentricity ratios (up to about 0.3). It is also clear that such a scaling law would become increasingly unsatisfactory as L/D becomes very large since all such coefficients remain finite for an infinitely long bearing. To improve the situation one requires the scaling factor to assume a finite asymptote as $L/D \rightarrow \infty$ and that a load level dependence be suitably included. A scaling factor which possesses these two properties can be derived by comparing the "half Sommerfeld" solution with the short bearing solution. The "half Sommerfeld" solution is described in Appendix C.

Suppose the scaling factor is defined as

$$\Sigma = \bar{W}/\bar{W}_{sh} \quad (67)$$

\bar{W} is the dimensionless load of any L/D and

$$\bar{W}_{sh} = \lim_{L/D \rightarrow 0} \frac{\bar{W}}{(L/D)^2} \quad (68)$$

The requirements indicated previously are satisfied if Σ is to be dependent on both L/D and \bar{W} . Thus

$$\Sigma = \Sigma(L/D, \bar{W});$$

and

$$\lim_{L/D \rightarrow 0} \Sigma = (L/D)^2$$

$$\lim_{L/D \rightarrow \infty} \Sigma = \Sigma_{\infty} < \infty \quad (69)$$

An empirical formula which is consistent with these conditions is

$$\Sigma = \frac{3}{2} \left[1 - \frac{\tanh(\alpha L/D)}{\alpha(L/D)} \right] \quad (70)$$

It is seen that

$$\lim_{L/D \rightarrow \infty} \Sigma = \Sigma_{\infty} = \frac{3}{2\alpha} \quad (71)$$

One can compute, with the aid of \bar{W}_{sh} and \bar{W}_{∞} derived in Appendices B and C,

$$\begin{aligned} \alpha &= \sqrt{\frac{3\bar{W}_{sh}}{\bar{W}_{\infty}}} \\ &= \sqrt{\frac{(2+\epsilon^2)}{2(1-\epsilon^2)}} \sqrt{\frac{1 - \{1 - (4/\pi)^2\}\epsilon^2}{1 - \{1 - (2/\pi)^2\}\epsilon^2}} \end{aligned} \quad (72)$$

ϵ , in turn can be regarded as a function of \bar{W}_{∞} . Since Eq. (70) is intended to exclude the effect of L/D , Eq. (72) can be construed to define the load scaling factor

$$\alpha(\bar{W}) = \alpha(\epsilon(\bar{W}_{\infty} = \bar{W})) \quad (73)$$

as shown in Fig. 5. It is seen that for a wide range of the load parameter, \bar{W} , α is hardly distinguishable from unity. Consequently, the value of $\alpha = 1.125$ (at $\bar{W} = 10.0$) should be quite satisfactory; thus

$$\Sigma = \frac{\bar{W}}{\bar{W}_{sh}} \approx 2.3704 \left[1 - \frac{\tanh(1.125 L/D)}{1.125 (L/D)} \right] \quad (74)$$

which would be used to scale the load parameter as well as the dimensionless dynamic coefficients.

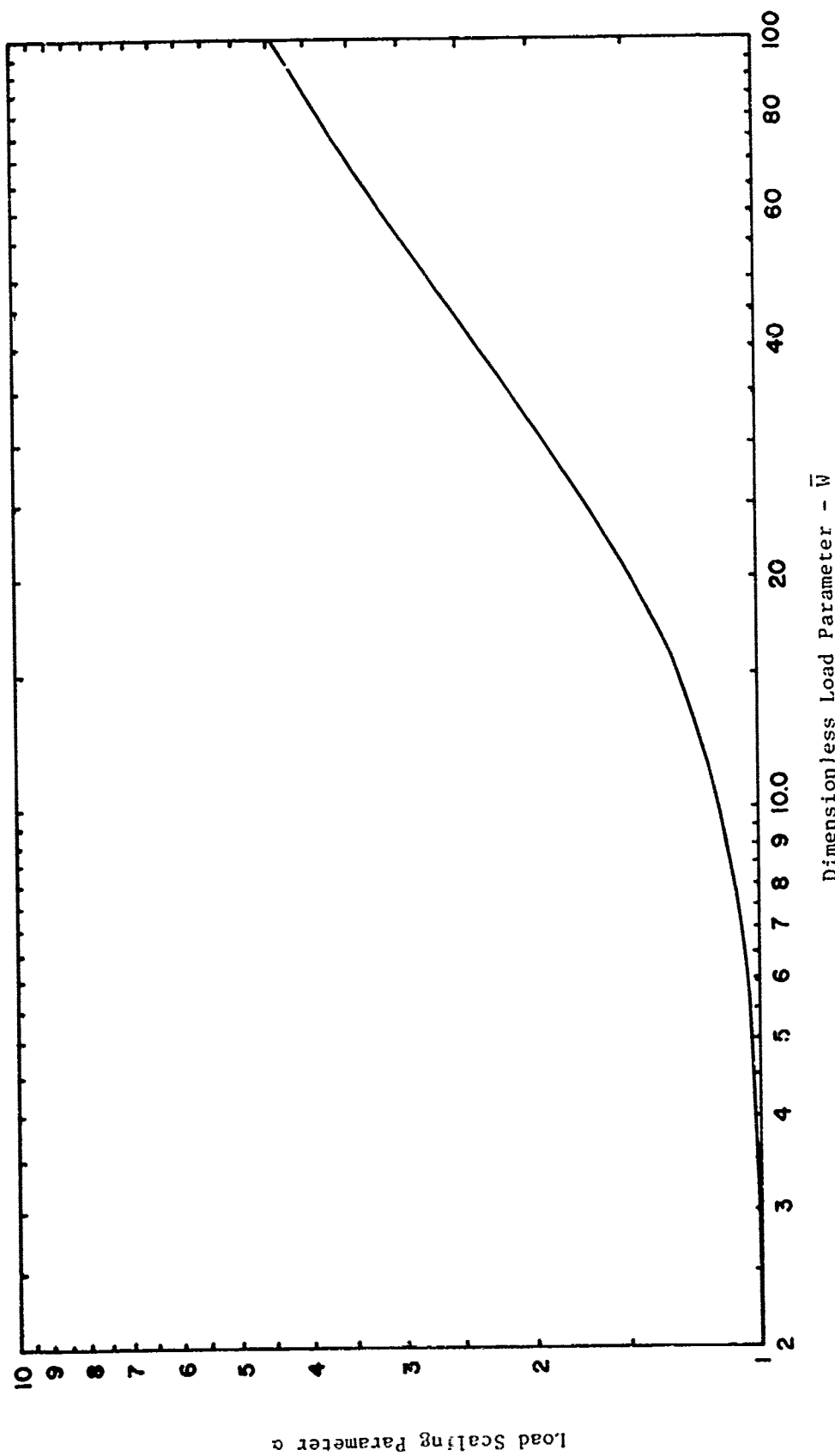


Figure 5 Load Scaling Parameter

For instance, if a data table for $L/D = 0.5$ is available, then

$$(\Sigma)_{\text{table}} = 0.22195$$

If the design under consideration is for $L/D = 1.0$, i.e.,

$$(\Sigma)_{\text{design}} = 0.66518$$

the effective load for the available table should be

$$(\bar{W})_{\text{table}} = \frac{0.22195}{0.66518} (\bar{W})_{\text{design}} = 0.3367 (\bar{W})_{\text{design}}$$

which would be used to interpolate in the data table to obtain

$$(\bar{K}_{xx}, \text{etc.}; \bar{B}_{xx}, \text{etc.})_{\text{table}}$$

Finally,

$$\begin{aligned} & (\bar{K}_{xx}, \text{etc.}; \bar{B}_{xx}, \text{etc.})_{\text{design}} \\ &= \frac{0.66518}{0.22195} (\bar{K}_{xx}, \text{etc.}; \bar{B}_{xx}, \text{etc.})_{\text{table}} \\ &= 2.9970 (\bar{K}_{xx}, \text{etc.}; \bar{B}_{xx}, \text{etc.})_{\text{table}} \end{aligned}$$

In this manner, a data table of a particular value of L/D can be reasonably used for designs of somewhat different L/D . This scaling procedure should not be used if there is significant preloading.

4.4 Data Smoothing

The full range interpolation procedure is sensitive to the presence of inaccurate data points. Numerically computed data points can be inaccurate for a variety of reasons; the most common ones are:

- faulty algorithm
- improper mesh (or function) setup, and
- inadequate convergence control

Unfortunately, such inaccuracies often show up even with "proven" softwares as run by an "experienced" user. Because the full range interpolation procedure is sensitive to inaccuracies in the data table, it can be used as the tool to uncover bad data points which should be adjusted.

Upon compiling a retrieval table, the comparison function and its spline interpolation coefficients (first, second, and third derivatives with respect to the working parameter) in each data interval are printed out. Lack of smoothness can be recognized at a glance by inspection of the sign of the first derivative. An isolated change of sign or a succession of sign reversals prominently mark the presence of bad data points.

Very often the inaccuracy associated with each data point is quite modest. But the error may be of alternate signs for a group of such data points in close range. In this case, the table is readily "fixed" by omitting some of the original data points. In some other instances, neighboring groups of data points depict an abrupt change. This is most likely caused by the necessity of employing a different input setup to obtain the data points of the two groups. It is then necessary to adjust one or more data points to permit smooth interpolation over the full range.

Fig. 6(a) shows an example of how "ripples" would be generated by the full range interpolation procedure. In this particular case, a number of data points of questionable accuracy were contained in the original data table as furnished [3]. "Data clutter" in a range of moderately high load level is probably due to loss of accuracy associated with the use of finite difference operation on "trajectory" points to compute the impedance

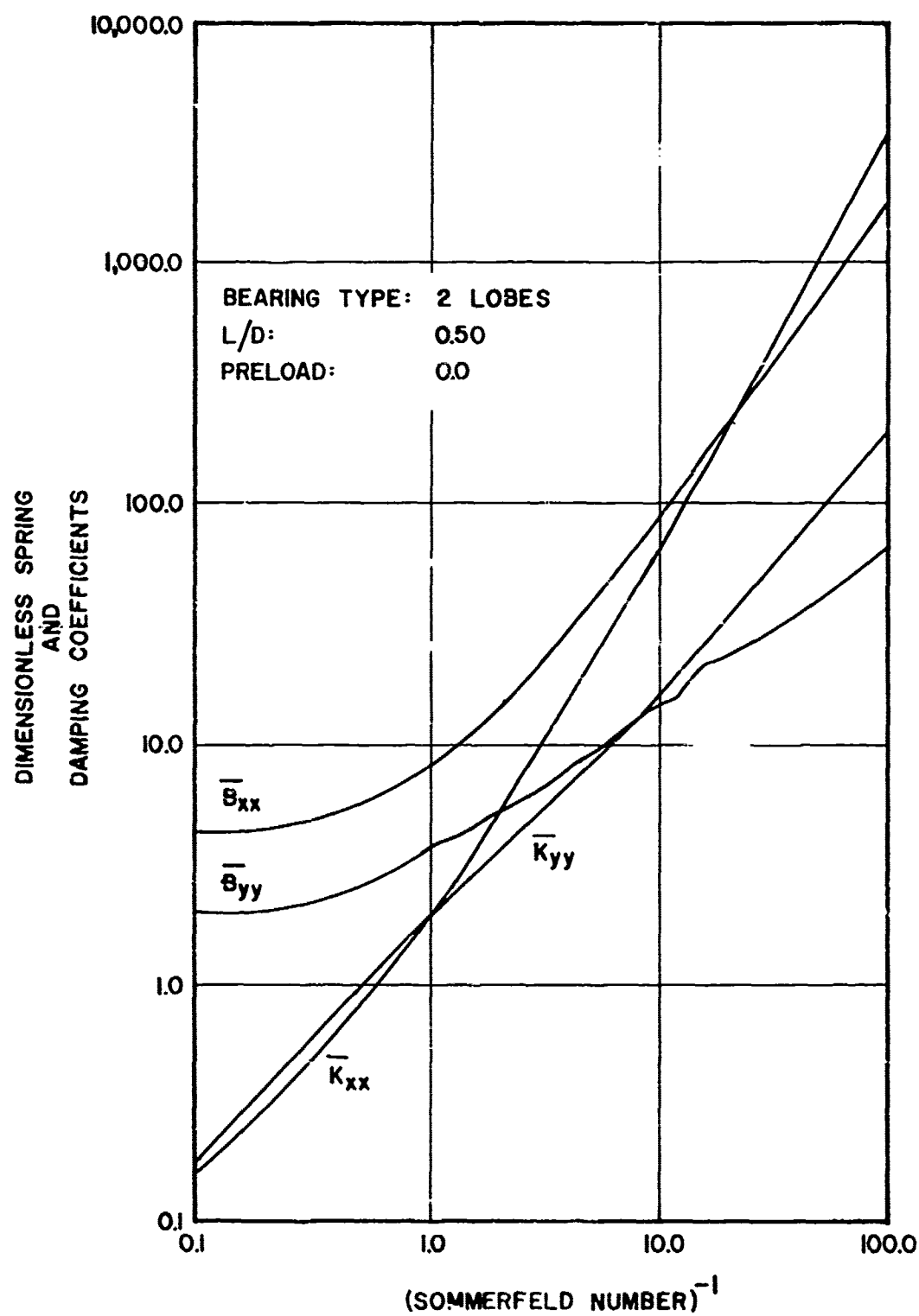


Figure 6(a) Ripples in Original Data

coefficients. Removal of "data clutter" by omitting six of the original seventeen data points permits smooth graphing by interpolation as shown in Fig. 6(b).

A thorough screening of each data table was performed. Adjustments and/or omissions are made where necessary. Therefore, the retrieval files as listed in Appendix D no longer correspond fully to the original data tables.

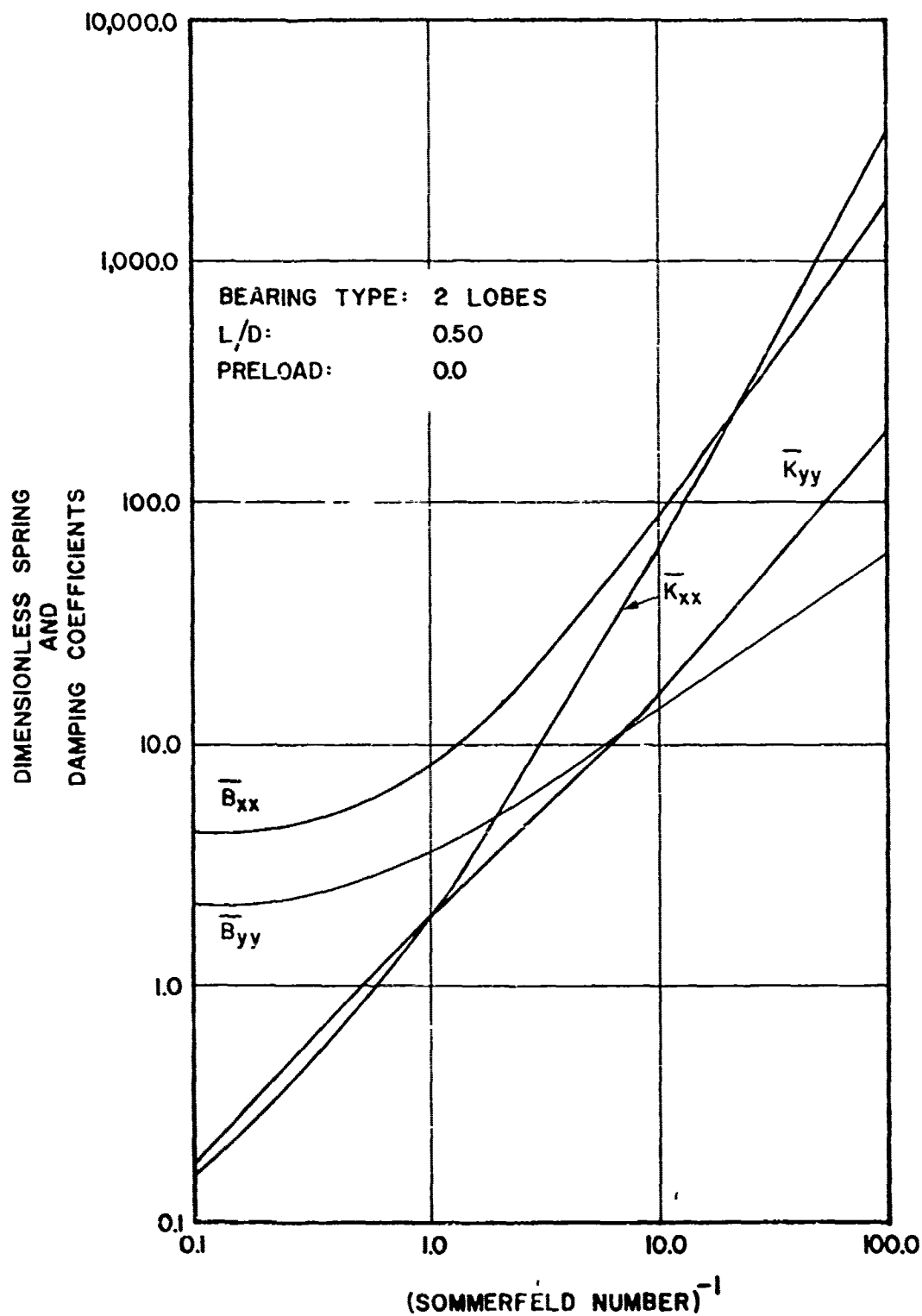


Figure 6(b) Smooth Curves upon Removal of Data Clutter

APPENDIX A

SAMPLE RUNS

The data retrieval software is designed primarily to prepare dynamic data of fluid film bearings for use as part of the input for running the Rotor System Vibrations Program (RSVP) [9]. In addition to extracting the necessary information from a stored data table, at user's command, it performs the supplementary functions of

- shifting the direction of load vector,
- adjusting the data for any deviation of L/D from that of the data table, and
- incorporation of foundation compliance with allowance for inertia and dissipation effects.

It may also be used simply to prepare a listing of the data table in either the dimensional or the dimensionless form in a load range specified by the user.

The software is coded in FORTRAN and is written in the interactive mode. It can thus be run on any computer system which provides the FORTRAN option and can be commanded from an interactive terminal. The bank of data tables may be located on either tape or disk type mass storage device. Thirty-one data tables are listed in Appendix D. The user may install additional data tables according to the procedure described in Section IV. The format of the data table is described in Section 3.4. The source listing of the software is given in Appendix E.

Several sample runs are shown on the following pages. Each sample includes:

- a record of the interactive session with the prompting messages enclosed in boxes;
- a complete output of bearing data for the applicable operating condition(s), including file identification, static characteristics, table of dynamic characteristics, effective stiffness/damping representation with descriptive headings; and

- as required, a listing of the data lines suitable for incorporation into the input setup for running the Rotor System Vibration Program.

The last listing can be punched out into data cards.

Brief descriptions of these sample runs with commentary on notable features are given below:

Sample 1 Synchronous Data with Anisotropic Foundation Compliance in Two Speed Groups, L/D Adjustment Accepted, Inclined Load

L/D of specified bearing (0.6667) is different from that of data table (0.50).

Load vector of bearing is inclined to the vertical direction by 30 degrees.

Foundation data includes inertia (weight) stiffness, and damping coefficients; the latter have distinct values in vertical and horizontal planes.

Sample 2 Synchronous Data with Rigid Foundation in Two Speed Groups, No L/D Adjustment

Same bearing as Sample 1, but L/D adjustment is suppressed. Load direction coincides with vertical direction. Same speed points in two groups as Sample 1.

Sample 3 Synchronous Data with Rigid Foundation in Two Speed Groups, L/D Adjustment Accepted

By comparison with Sample 11, this sample shows the effect of L/D adjustment.

Sample 4

Synchronous Data with Rigid Foundation in Three Speed Groups,
L/D Adjustment Accepted, Inclined Load.

By comparison with Sample III, this sample shows that the dynamic coefficients vary with the load direction, but the static characteristics as well as the stiffness/damping representation are independent of the load direction.

This run also shows the capability of generating data for a third speed group.

Sample 5

Asynchronous Data with Rigid Foundation, Two Frequency
Groups at the Same Speed, L/D Matched with Data Table

A single data line of dynamic characteristics is shown for each frequency group because such data for the bearing on rigid foundation is independent of frequency.

Sample 6

Asynchronous Data with Isotropic Foundation Compliance

Foundation has an isotropic elastic compliance, (reciprocal of stiffness) but no inertia and damping effects. The overall dynamic coefficients become frequency dependent and are thus generated at each frequency.

SAMPLE 1

RECORD OF INTERACTIVE SESSION

ENTER DATA TABLE NAME: P.I-05-1
ENTER OUTPUT FILE NAME: OUTPUT

SELECT: (1) PREPARE DATA FOR RSVP INPUT
(2) DIMENSIONAL TABLE
(3) DIMENSIONLESS TABLE
(4) QUIT

1

SELECT: (1) SYNCH FREQ, OR
(2) ASYNCH FREQ?

1

ENTER BEARING LENGTH (IN)

1.0

ENTER BEARING DIAMETER (IN)

1.5

ENTER BEARING CLEARANCE (IN)

0.001

ENTER VISCOSITY (CENTI-POISE)

40.0

ENTER BEARING LOAD (LBS)

750.0

ENTER BEARING COEFS FILE NAME: RSVP

SELECT: (1) USE DEFAULT L/D = 0.5000
(2) ADJUST DATA FOR L/D = 0.6667

2

SELECT: (1) LOAD VECTOR IN VERTICAL PLANE, OR
(2) INCLINED LOAD VECTOR?

2

ENTER LOAD INCLINATION ANGLE (DEG)?

50.0

SELECT: (1) RIGID FOUNDATION
(2) ISOTROPIC FOUNDATION COMPLIANCE, OR
(3) ANISOTROPIC FOUNDATION COMPLIANCE?

3

SELECT: (1) RADIAL BEARING, OR
(2) ANGULAR BEARING?

1

ENTER PEDESTAL WEIGHT (LB)?

120.0

ENTER PEDESTAL STIFFNESS IN VERTICAL PLANE?
(LB/IN) FOR RADIAL BRG, OR (IN-LB/RAD) FOR ANG BRG

2 50+04

ENTER PEDESTAL STIFFNESS IN HORIZONTAL PLANE
(LB/IN) FOR RADIAL BRG, OR (IN-LB/RAD) FOR ANG BRG

1.00+04

ENTER PEDESTAL DAMPING IN VERTICAL PLANE?
(LB-SEC/IN) FOR RAD BRG, OR (IN-LB-SEC/RAD) FOR ANG BRG

10.0

Sample 1 - Record of Interactive Session (continued)

ENTER PEDESTAL DAMPING IN HORIZONTAL PLANE?
(LB-SEC/IN) FOR RAD BRG, OR (IN-LB-SEC/RAD) FOR ANG BPG

25.0

ENTER LOWEST SPEED (RPM)

6000.0

ENTER HIGHEST SPEED (RPM)

9000.0

ENTER NUMBER OF SPEED POINTS (NOT MORE THAN 11)

11

SELECT - (1) ANOTHER SPEED GROUP
(2) QUIT

1

ENTER LOWEST SPEED (RPM)

9000.0

ENTER HIGHEST SPEED (RPM)

12000.0

ENTER NUMBER OF SPEED POINTS (NOT MORE THAN 11)

11

SELECT - (1) ANOTHER SPEED GROUP
(2) QUIT

2

RETRIEVAL FILE NO P0-05-1
 FILE SIZE = 17
 L/D = 0 5000
 HLFA = 1 1250

SAMPLE 1

TABULATION OF BEARING DATA

L (IN) DIA (IN) C (IN) VISC (CP) W (LBS) SPEED RANGE (RPM)
 1 0000 1 5000 0 001000 4.0000 01 750 00 6000.00 TO 9000.00 11 FTS

LOAD PARAMETER IS ADJUSTED FOR L/D = 0.6667

RPM	ECC(IN)	ATT ANGLE	FRICT(HP)	Q-REQ(GPM)	Q-LOST(GPM)
6 0000 03	3.41710-04	6.88050 01	8.60800-04	8.00480-02	3.82000-02
6 2480 03	3.32320-04	6.94020 01	9.32570-04	8.28270-02	3.86850-02
6 50680 03	3.23020-04	6.99940 01	1.01050-03	8.57050-02	3 91560-02
6 77610 03	3.13830-04	7.05820 01	1.09510-03	8.86860-02	3.96140-02
7 05650 03	3.04760-04	7.11640 01	1.18710-03	9.17750-02	4.00590-02
7 34850 03	2.95810-04	7.17410 01	1.28690-03	9.49760-02	4.04890-02
7 65250 03	2.86980-04	7.23120 01	1.39530-03	9.82940-02	4.09050-02
7 96920 03	2.78290-04	7.28730 01	1.51300-03	1.01730-01	4.13050-02
8 29900 03	2.69720-04	7.34250 01	1.64100-03	1.05300-01	4.16880-02
8 64240 03	2.61280-04	7.39660 01	1.77990-03	1.08990-01	4.20540-02
9 00000 03	2.52980-04	7.44940 01	1.93090-03	1.12830-01	4.24020-02

LOAD AND DYNAMIC COEFFICIENTS ARE ADJUSTED FOR L/D = 0.6667

RPM	K-XX	B-XX	K-XY	B-XY	K-YY	B-YY
6.0000 03-9.8630 04	1.5930	01-1.0360	03-3.0210	00 1.9820	03-3.4880-01-1.1340	05 2.9700 01
6.2480 03-1.0920 05	1.6780	01-1.2590	03-3.3420	00 2.3410	03-3.7580-01-1.2390	05 3.0290 01
6 5070 03-1.2060 05	1.7730	01-1.5260	03-3.6830	00 2.7570	03-4.0810-01-1.3520	05 3.0940 01
6 7760 03-1.3300 05	1.8770	01-1.8440	03-4.0440	00 3.2390	03-4.4730-01-1.4760	05 3.1670 01
7 0560 03-1.4640 05	1.9920	01-2.2220	03-4.4270	00 3.7950	03-4.9560-01-1.6090	05 3.2490 01
7 3480 03-1.6090 05	2.1180	01-2.6700	03-4.8320	00 4.4370	03-5.5420-01-1.7540	05 3.3390 01
7 6530 03-1.7670 05	2.2570	01-3.2000	03-5.2580	00 5.1770	03-6.2590-01-1.9120	05 3.4390 01
7 9690 03-1.9380 05	2.4100	01-3.8240	03-5.7040	00 6.0280	03-7.1370-01-2.0820	05 3.5510 01
8 2990 03-2.1240 05	2.5770	01-4.5590	03-6.1700	00 7.0050	03-8.2080-01-2.2680	05 3.6740 01
8 6420 03-2.3250 05	2.7590	01-5.4210	03-6.6530	00 8.1240	03-9.5090-01-2.4680	05 3.8100 01
9.0000 03-2.5420 05	2.9590	01-6.4300	03-7.1540	00 9.4050	03-1.1080 00-2.6860	05 3.9610 01

Sample 1 - Tabulation of Bearing Data (continued)

*****SYNCH BPG CHARACTERISTICS*****										STABILITY PARAMETERS	
*****										*****	
RPM	ECC (IN)	ATT ANGLE	FRICT (HP)	O-REQ (GPM)	O-LOST (GPM)						
9 00000 03	2.52980-04	7.44940 01	1.93090-03	1.12830-01	4.24020-02						UNCONDITIONALLY STABLE
9 26270 03	2.47180-04	7.48600 01	2.04590-03	1.15630-01	4.26380-02						UNCONDITIONALLY STABLE
9 53300 03	2.41450-04	7.52190 01	2.16790-03	1.18510-01	4.28640-02						UNCONDITIONALLY STABLE
9 81120 03	2.35800-04	7.55700 01	2.29730-03	1.21460-01	4.30810-02						UNCONDITIONALLY STABLE
1 00960 04	2.30220-04	7.59140 01	2.43450-03	1.24490-01	4.32880-02						UNCONDITIONALLY STABLE
1 03920 04	2.24720-04	7.62490 01	2.58010-03	1.27600-01	4.34860-02						UNCONDITIONALLY STABLE
1 06960 04	2.19300-04	7.65750 01	2.73460-03	1.30790-01	4.36740-02						UNCONDITIONALLY STABLE
1 10080 04	2.13960-04	7.68930 01	2.89850-03	1.34070-01	4.38530-02						UNCONDITIONALLY STABLE
1 13290 04	2.08700-04	7.72020 01	3.07230-03	1.37430-01	4.40220-02						UNCONDITIONALLY STABLE
1 16600 04	2.03520-04	7.75020 01	3.25670-03	1.40880-01	4.41830-02						UNCONDITIONALLY STABLE
1 20000 04	1.98430-04	7.77930 01	3.45240-03	1.44420-01	4.43340-02						UNCONDITIONALLY STABLE

LONG PARAMETER IS ADJUSTED FOR L/D = 0.6667

Sample 1 - Tabulation of Bearing Data (continued)

LOAD AND DYNAMIC COEFFICIENTS ARE ADJUSTED FOR L/D = 0.6667

RPM	K-XX	B-XX	K-XY	B-XY	K-YX	B-YX	K-YY	B-YY
9 0000	03-2 5420	05 2 9590	01-6 4300	03-7 1540	00 9 4050	03-1 1080	00-2 6860	05 3 9610
9 2630	03-2 7080	05 3 1110	01-7 2470	03-7 5170	00 1 0420	04-1 2390	00-2 9510	05 4 0770
9 5330	03-2 8830	05 3 2730	01-8 1580	03-7 8860	00 1 1540	04-1 3880	00-3 0260	05 4 2020
9 8110	03-3 0680	05 3 4450	01-9 1720	03-8 2600	00 1 2770	04-1 5560	00-3 2110	05 4 3350
1 0100	04-3 2640	05 3 6280	01-1 0300	04-8 6380	00 1 4110	04-1 7460	00-3 4070	05 4 4720
1 0390	04-3 4710	05 3 8220	01-1 1550	04-9 0170	00 1 5580	04-1 9610	00-3 6150	05 4 6290
1 0700	04-3 6910	05 4 0270	01-1 2940	04-9 3960	00 1 7180	04-2 2020	00-3 8340	05 4 7920
1 1010	04-3 9230	05 4 2440	01-1 4480	04-9 7740	00 1 8940	04-2 4730	00-4 0670	05 4 9650
1 1330	04-4 1680	05 4 4740	01-1 6180	04-1 0150	01 2 0860	04-2 7750	00-4 3130	05 5 1500
1 1660	04-4 4270	05 4 7180	01-1 8070	04-1 0520	01 2 2950	04-3 1110	00-4 5730	05 5 3470
1 2000	04-4 7020	05 4 9760	01-2 0150	04-1 0870	01 2 5230	04-3 4870	00-4 8490	05 5 5560

PARAM	MIN	STIFF	BRG	CHARACTERISTICS	WAVE	AMP	PHASE	STABILITY	PERMETERS
9.00000	03-2	68160	05	7.79260-02	-2	54630	05	4.59990-02	UNCONDITIONALLY STABLE
9.26270	03-2	84640	05	7.89170-02	-2	71220	05	4.58290-02	UNCONDITIONALLY STABLE
9.53300	03-3	02090	05	7.98670-02	-2	88760	05	4.56560-02	UNCONDITIONALLY STABLE
9.81120	03-3	20570	05	8.10670-02	-3	07330	05	4.54880-02	UNCONDITIONALLY STABLE
1.00980	04-3	40140	05	8.24090-02	-3	26960	05	4.53300-02	UNCONDITIONALLY STABLE
1.03920	04-3	60860	05	8.38850-02	-3	47730	05	4.51890-02	UNCONDITIONALLY STABLE
1.06960	04-3	82800	05	8.54850-02	-3	69690	05	4.50700-02	UNCONDITIONALLY STABLE
1.10080	04-4	06010	05	8.72040-02	-3	92920	05	4.49780-02	UNCONDITIONALLY STABLE
1.13290	04-4	30560	05	8.90360-02	-4	17500	05	4.49170-02	UNCONDITIONALLY STABLE
1.16600	04-4	56530	05	9.09850-02	-4	42500	05	4.48910-02	UNCONDITIONALLY STABLE
2.00000	04-4	83990	05	9.30310-02	-4	71000	05	4.49000-02	UNCONDITIONALLY STABLE

SAMPLE 1

DATA LINES IN RSVP FORMAT

```

-9.8630 04 1.5930 01-1.0360 03-3.0210 00 1.9820 03-3 4380-01-1 1340 05 2 3700 01
-1.0920 05 1.6780 01-1.2590 03-3.3420 00 2 3410 03-3 7580-01-1.2390 05 3 0290 01
-1.2060 05 1.7730 01-1.5260 03-3.6930 00 2 7570 03-4 0810-01-1.3520 05 3 0940 01
-1.3300 05 1.8770 01-1.8440 03-4.0440 00 3 2390 03-4 4730-01-1.4760 05 3 1670 01
-1.4640 05 1.9920 01-2.2220 03-4.4270 00 3 7950 03-4 9560-01-1.6090 05 3 2490 01
-1.6090 05 2.1180 01-2.6700 03-4.8320 00 4 4370 03-5 5420-01-1.7540 05 3 3390 01
-1.7670 05 2.2570 01-3.2000 03-5.2580 00 5 1770 03-6 2590-01-1.9120 05 3 4390 01
-1.9380 05 2.4100 01-3.8240 03-5.7040 00 6 0280 03-7 1370-01-2.0820 05 3 5510 01
-2.1240 05 2.5770 01-4.5590 03-6.1700 00 7 0050 03-8 2080-01-2.2680 05 3 6740 01
-2.3250 05 2.7590 01-5.4210 03-6.6530 00 8 1240 03-9 5090-01-2.4680 05 3 8100 01
-2.5420 05 2.9590 01-6.4300 03-7.1540 00 9 4050 03-1 1080 00-2.6860 05 3 9610 01
-2.5420 05 2.9590 01-6.4300 03-7.1540 00 9 4050 03-1 1080 00-2.6860 05 3 9610 01
-2.7080 05 3.1110 01-7.2470 03-7.5170 00 1 0420 04-1 2390 00-2.8510 05 4 0770 01
-2.8830 05 3.2730 01-8.1580 03-7.8860 00 1 1540 04-1 3880 00-3.0260 05 4 2020 01
-3.0680 05 3.4450 01-9.1720 03-8.2600 00 1 2770 04-1 5560 00-3.2110 05 4 3350 01
-3.2640 05 3.6280 01-1 0300 04-8.6380 00 1 4110 04-1 7460 00-3.4070 05 4 4770 01
-3.4710 05 3.8220 01-1.1550 04-9 0170 00 1 5580 04-1 9610 00-3.6150 05 4 6290 01
-3.6910 05 4.0270 01-1.2940 04-9.3960 00 1 7180 04-2 2020 00-3.8340 05 4 7920 01
-3.9230 05 4.2440 01-1.4480 04-9.7740 00 1 8940 04-2 4730 00-4.0670 05 4 9650 01
-4.1680 05 4.4740 01-1.6180 04-1.0150 01 2 0860 04-2 7750 00-4.3130 05 5 1500 01
-4.4270 05 4.7180 01-1.8070 04-1 0520 01 2 2950 04-3 1110 00-4.5730 05 5 3470 01
-4.7020 05 4.9760 01-2.0150 04-1.0870 01 2 5230 04-3 4870 00-4.8480 05 5 5560 01

```

SAMPLE 2

RECORD OF INTERACTIVE SESSION

ENTER DATA TABLE NAME: PJ-05-1
ENTER OUTPUT FILE NAME: OUTPUT

SELECT: (1) PREPARE DATA FOR RSVP INPUT
(2) DIMENSIONAL TABLE
(3) DIMENSIONLESS TABLE
(4) QUIT

1
SELECT: (1) SYNCH FREQ, OR
(2) ASYNCH FREQ?

1
ENTER BEARING LENGTH (IN)

1.0

ENTER BEARING DIAMETER (IN)

1.5

ENTER BEARING CLEARANCE (IN)

0.001

ENTER VISCOSITY (CENTI-POISE)

40.0

ENTER BEARING LOAD (LBS)

750.0

ENTER BEARING COEFS FILE NAME: RSVP

SELECT: (1) USE DEFAULT L/D = 0.5000
(2) ADJUST DATA FOR L/D = 0.6667

1
SELECT: (1) LOAD VECTOR IN VERTICAL PLANE, OR
(2) INCLINED LOAD VECTOR?

1
SELECT: (1) RIGID FOUNDATION
(2) ISOTROPIC FOUNDATION COMPLIANCE, OR
(3) ANISOTROPIC FOUNDATION COMPLIANCE?

1
ENTER LOWEST SPEED (RPM)

6000.0

ENTER HIGHEST SPEED (RPM)

9000.0

ENTER NUMBER OF SPEED POINTS (NOT MORE THAN 11)

11

Sample 2 - Record of Interactive Session (continued)

SELECT - (1) ANOTHER SPEED GROUP
(2) QUIT

1

ENTER LOWEST SPEED (RPM)

9000.0

ENTER HIGHEST SPEED (RPM)

12000.0

ENTER NUMBER OF SPEED POINTS (NOT MORE THAN 11)

11

SELECT - (1) ANOTHER SPEED GROUP
(2) QUIT

2

RETRIEVAL FILE NO PJ-05-1

FILE SIZE = 17
L/D = 0.5000
ALFA = 1.1250

SAMPLE 2

TABULATION OF BEARING DATA

L (IN)	DIA (IN)	C (IN)	VISC (CP)	W (LBS)	SPEED RANGE (RPM)	PTS
1.0000	1.5000	0.001000	4.0000 01	750.00	6000.00 TO 9000.00	11

RPM	ECC (IN)	ATT ANGLE	FRICT (HP)	Q-REQ (GPM)	Q-LOST (GPM)
6.00000 03	4.59160-04	6.12760 01	8.86610-04	8.63990-02	5.14030-02
6.24830 03	4.49470-04	6.19070 01	9.57960-04	8.94330-02	5.23910-02
6.50680 03	4.39750-04	6.25390 01	1.03530-03	9.25670-02	5.33720-02
6.77610 03	4.30030-04	6.31720 01	1.11910-03	9.58070-02	5.43430-02
7.05650 03	4.20300-04	6.38040 01	1.20990-03	9.91550-02	5.53040-02
7.34850 03	4.10560-04	6.44340 01	1.30840-03	1.02610-01	5.62500-02
7.65250 03	4.00820-04	6.50600 01	1.41520-03	1.06190-01	5.71810-02
7.96920 03	3.91080-04	6.56820 01	1.53120-03	1.09880-01	5.80930-02
8.29900 03	3.81350-04	6.62990 01	1.65710-03	1.13700-01	5.89870-02
8.64240 03	3.71670-04	6.69120 01	1.79380-03	1.17650-01	5.98620-02
9.00000 03	3.62030-04	6.75200 01	1.94220-03	1.21730-01	6.07170-02

RPM	K-XX	B-XX	K-XY	B-XY	K-YX	B-YX	K-YY	B-YY
6.0000 03	1.5040 06	7.7460 06	2.7480 03	2.9160 03-1	0.260 06	2.9160 06	1.5280 03	4.5650 03
6.2480 03	1.4690 06	7.4790 06	2.7570 03	2.7940 03-1	0.750 06	2.7940 06	1.5310 03	4.4870 03
6.5070 03	1.4360 06	7.2260 06	2.7670 03	2.6780 03-1	1.250 06	2.6780 06	1.5350 03	4.4120 03
6.7760 03	1.4040 06	6.9870 06	2.7790 03	2.5660 03-1	1.770 06	2.5660 06	1.5380 03	4.3400 03
7.0560 03	1.3730 06	6.7620 06	2.7930 03	2.4590 03-1	2.310 06	2.4590 06	1.5410 03	4.2710 03
7.3480 03	1.3440 06	6.5500 06	2.8090 03	2.3570 03-1	2.860 06	2.3570 06	1.5450 03	4.2040 03
7.6530 03	1.3150 06	6.3500 06	2.8280 03	2.2590 03-1	3.440 06	2.2590 06	1.5480 03	4.1410 03
7.9690 03	1.2880 06	6.1620 06	2.8490 03	2.1660 03-1	4.040 06	2.1660 06	1.5510 03	4.0800 03
8.2990 03	1.2620 06	5.9840 06	2.8730 03	2.0760 03-1	4.660 06	2.0760 06	1.5540 03	4.0210 03
8.6420 03	1.2360 06	5.8170 06	2.8990 03	1.9910 03-1	5.200 06	1.9910 06	1.5570 03	3.9650 03
9.0000 03	1.2120 06	5.6600 06	2.9290 03	1.9090 03-1	5.960 06	1.9090 06	1.5600 03	3.9110 03

Sample 2 - Tabulation of Bearing Data

L (IN) DIA (IN) C (IN) VISC (CP) W (LBS) SPEED RANGE (RPM) 11 PTS
 1.0000 1.5000 0.001000 4.0000 01 750 00 9000 00 TO 12000.00

RPM	*****SYNCH BRG CHARACTERISTICS*****				*****		STABILITY		PARAMETERS		
	MIN	STIFF	MIN DAMP	NRJ	STIFF	MAX GUNS	CP	NRSS	F	RATIO	
6.00000	03	9.4421D	05	5.9765D-01	2.0876D	06	1.5824D	00	1.0218D	04	5.3047D-01
6.2483D	03	9.5235D	05	6.1143D-01	2.0484D	06	1.6268D	00	1.0232D	04	5.3115D-01
6.5068D	03	9.6058D	05	6.2569D-01	2.0104D	06	1.6733D	00	1.0248D	04	5.3176D-01
6.7761D	03	9.6888D	05	6.4046D-01	1.9734D	06	1.7220D	00	1.0266D	04	5.3229D-01
7.0565D	03	9.7724D	05	6.5577D-01	1.9376D	06	1.7731D	00	1.0287D	04	5.3276D-01
7.3485D	03	9.8566D	05	6.7162D-01	1.9028D	06	1.8267D	00	1.0309D	04	5.3318D-01
7.6525D	03	9.9413D	05	6.8805D-01	1.8691D	06	1.8830D	00	1.0332D	04	5.3356D-01
7.9692D	03	1.0027D	06	7.0505D-01	1.8364D	06	1.9421D	00	1.0355D	04	5.3392D-01
8.2990D	03	1.0112D	06	7.2267D-01	1.8046D	06	2.0042D	00	1.0378D	04	5.3425D-01
8.6424D	03	1.0198D	06	7.4092D-01	1.7739D	06	2.0695D	00	1.0402D	04	5.3456D-01
9.0000D	03	1.0284D	06	7.5986D-01	1.7441D	06	2.1791D	00	1.0425D	04	5.3486D-01

RPM	ECC(IN)	ATT ANGLE	FRICT(HP)	Q-REQ(GPM)		Q-LOST(GPM)	
				Q-REQ(GPM)	Q-LOST(GPM)		
9.0000D	03	3.6203D-04	6.7520D 01	1.9422D-03	1.2173D-01	6.0717D-02	
9.2627D	03	3.5523D-04	6.7950D 01	2.0551D-03	1.2471D-01	6.1312D-02	
9.5330D	03	3.4847D-04	6.8377D 01	2.1748D-03	1.2777D-01	6.1897D-02	
9.8112D	03	3.4175D-04	6.8803D 01	2.3017D-03	1.3090D-01	6.2471D-02	
1.0098D	04	3.3507D-04	6.9227D 01	2.4362D-03	1.3411D-01	6.3035D-02	
1.0392D	04	3.2844D-04	6.9648D 01	2.5789D-03	1.3739D-01	6.3589D-02	
1.0696D	04	3.2186D-04	7.0068D 01	2.7301D-03	1.4077D-01	6.4132D-02	
1.1008D	04	3.1534D-04	7.0485D 01	2.8904D-03	1.4422D-01	6.4664D-02	
1.1329D	04	3.0888D-04	7.0900D 01	3.0603D-03	1.4777D-01	6.5185D-02	
1.1660D	04	3.0248D-04	7.1311D 01	3.2406D-03	1.5140D-01	6.5694D-02	
1.2000D	04	2.9614D-04	7.1720D 01	3.4317D-03	1.5513D-01	6.6192D-02	

Sample 2 - Tabulation of Tearing Data (continued)

RPM	K-XX	B-XX	K-XY	B-XY	K-YX	B-YX	K-YY	B-YY
9.0000 03	1.2120 06	5.6600 03	2.9290 06	1.9090 03	1.5960 06	1.9090 03	1.5600 06	3.9110 03
9.2630 03	1.1960 06	5.5550 03	2.9510 06	1.8530 03	1.6450 06	1.8530 03	1.5620 06	3.8740 03
9.5330 03	1.1790 06	5.4540 03	2.9750 06	1.7780 03	1.6950 06	1.7990 03	1.5640 06	3.8380 03
9.8110 03	1.1640 06	5.3570 03	3.0010 06	1.7450 03	1.7470 06	1.7450 03	1.5660 06	3.8030 03
1.0100 04	1.1490 06	5.2640 03	3.0280 06	1.6940 03	1.7990 06	1.6940 03	1.5680 06	3.7690 03
1.0390 04	1.1340 06	5.1760 03	3.0570 06	1.6450 03	1.8540 06	1.6450 03	1.5700 06	3.7360 03
1.0700 04	1.1200 06	5.0910 03	3.0880 06	1.5970 03	1.9090 06	1.5970 03	1.5720 06	3.7030 03
1.1010 04	1.1060 06	5.0100 03	3.1200 06	1.5500 03	1.9660 06	1.5500 03	1.5740 06	3.6720 03
1.1330 04	1.0920 06	4.9320 03	3.1540 06	1.5050 03	2.0250 06	1.5050 03	1.5750 06	3.6410 03
1.1660 04	1.0790 06	4.8590 03	3.1900 06	1.4610 03	2.0850 06	1.4610 03	1.5770 06	3.6110 03
1.2000 04	1.0660 06	4.7880 03	3.2280 06	1.4180 03	2.1470 06	1.4180 03	1.5790 06	3.5820 03

RPM	MIN	STIFF	SYNTH	BRG	CHARACTERISTICS	MAJ	STIFF	MAJ	DAMP	STABILITY	PARAMETERS
										CP MASS	F RATIO
9.00000 03	1.02840 06	7.59860-01	1.74410 06	2.13810 00	1.74410 06	2.13810 00	1.04250 04	5.34860-01			
9.26270 03	1.03440 06	7.73720-01	1.72350 06	2.18890 00	1.72350 06	2.18890 00	1.04410 04	5.35050-01			
9.53300 03	1.04040 06	7.87960-01	1.70330 06	2.24150 00	1.70330 06	2.24150 00	1.04580 04	5.35240-01			
9.81120 03	1.04640 06	8.02570-01	1.68370 06	2.29600 00	1.68370 06	2.29600 00	1.04730 04	5.35420-01			
1.00980 04	1.05240 06	8.17570-01	1.66440 06	2.35250 00	1.66440 06	2.35250 00	1.04890 04	5.35600-01			
1.03920 04	1.05830 06	8.32980-01	1.64560 06	2.41090 00	1.64560 06	2.41090 00	1.05040 04	5.35780-01			
1.06960 04	1.06420 06	8.48790-01	1.62720 06	2.47150 00	1.62720 06	2.47150 00	1.05180 04	5.35960-01			
1.10080 04	1.07000 06	8.65040-01	1.60930 06	2.53420 00	1.60930 06	2.53420 00	1.05320 04	5.36130-01			
1.13290 04	1.07540 06	8.81710-01	1.59170 06	2.59920 00	1.59170 06	2.59920 00	1.05450 04	5.36320-01			
1.16600 04	1.08130 06	8.98900-01	1.57450 06	2.66670 00	1.57450 06	2.66670 00	1.05590 04	5.36480-01			
1.20000 04	1.08720 06	9.16490-01	1.55780 06	2.73640 00	1.55780 06	2.73640 00	1.05700 04	5.36670-01			

SAMPLE 2

DATA LINES IN RSVP FORMAT

1.5040	06	7.7460	03	2.7480	06	2.9160	03-1.0260	06	2.9160	03	1.5280	06	4.5650	03
1.4690	06	7.4790	03	2.7570	06	2.7940	03-1.0750	06	2.7940	03	1.5310	06	4.4870	03
1.4360	06	7.2260	03	2.7670	06	2.6780	03-1.1250	06	2.6780	03	1.5350	06	4.4120	03
1.4040	06	6.9870	03	2.7790	06	2.5660	03-1.1770	06	2.5660	03	1.5380	06	4.3400	03
1.3730	06	6.7620	03	2.7930	06	2.4590	03-1.2310	06	2.4590	03	1.5410	06	4.2710	03
1.3440	06	6.5500	03	2.8090	06	2.3570	03-1.2860	06	2.3570	03	1.5450	06	4.2040	03
1.3150	06	6.3500	03	2.8280	06	2.2590	03-1.3440	06	2.2590	03	1.5480	06	4.1410	03
1.2880	06	6.1620	03	2.8490	06	2.1660	03-1.4040	06	2.1660	03	1.5510	06	4.0800	03
1.2620	06	5.9840	03	2.8730	06	2.0760	03-1.4660	06	2.0760	03	1.5540	06	4.0210	03
1.2360	06	5.8170	03	2.8990	06	1.9910	03-1.5300	06	1.9910	03	1.5570	06	3.9650	03
1.2120	06	5.6600	03	2.9290	06	1.9090	03-1.5960	06	1.9090	03	1.5600	06	3.9110	03
1.2120	06	5.6600	03	2.9290	06	1.9090	03-1.5960	06	1.9090	03	1.5600	06	3.9110	03
1.1960	06	5.5550	03	2.9510	06	1.8530	03-1.6450	06	1.8530	03	1.5620	06	3.8740	03
1.1790	06	5.4540	03	2.9750	06	1.7980	03-1.6950	06	1.7980	03	1.5640	06	3.8380	03
1.1640	06	5.3570	03	3.0010	06	1.7450	03-1.7470	06	1.7450	03	1.5660	06	3.8030	03
1.1490	06	5.2640	03	3.0280	06	1.6940	03-1.7990	06	1.6940	03	1.5680	06	3.7690	03
1.1340	06	5.1760	03	3.0570	06	1.6450	03-1.8540	06	1.6450	03	1.5700	06	3.7360	03
1.1200	06	5.0910	03	3.0880	06	1.5970	03-1.9090	06	1.5970	03	1.5720	06	3.7030	03
1.1060	06	5.0100	03	3.1200	06	1.5500	03-1.9660	06	1.5500	03	1.5740	06	3.6720	03
1.0920	06	4.9320	03	3.1540	06	1.5050	03-2.0250	06	1.5050	03	1.5750	06	3.6410	03
1.0790	06	4.8590	03	3.1900	06	1.4610	03-2.0850	06	1.4610	03	1.5770	06	3.6110	03
1.0660	06	4.7880	03	3.2280	06	1.4180	03-2.1470	06	1.4180	03	1.5790	06	3.5820	03

SAMPLE 3

RECORD OF INTERACTIVE SESSION

ENTER DATA TABLE NAME: PJ-05-1
ENTER OUTPUT FILE NAME: OUTPUT

SELECT: (1) PREPARE DATA FOR RSVP INPUT
(2) DIMENSIONAL TABLE
(3) DIMENSIONLESS TABLE
(4) QUIT

1

SELECT: (1) SYNCH FREQ, OR
(2) ASYNCH FREQ?

1

ENTER BEARING LENGTH (IN)

1.0

ENTER BEARING DIAMETER (IN)

1.5

ENTER BEARING CLEARANCE (IN)

0.001

ENTER VISCOSITY (CENTI-POISE)

40.0

ENTER BEARING LOAD (LBS)

750.0

ENTER BEARING COEFS FILE NAME: RSVP

SELECT: (1) USE DEFAULT L/D = 5000
(2) ADJUST DATA FOR L/D = 0.6667

2

SELECT: (1) LOAD VECTOR IN VERTICAL PLANE, OR
(2) INCLINED LOAD VECTOR?

1

SELECT: (1) RIGID FOUNDATION
(2) ISOTROPIC FOUNDATION COMPLIANCE, OR
(3) ANISOTROPIC FOUNDATION COMPLIANCE?

1

ENTER LOWEST SPEED (RPM)

6000.0

ENTER HIGHEST SPEED (RPM)

9000.0

ENTER NUMBER OF SPEED POINTS (NOT MORE THAN 11)

11

Sample 3 - Record of Interactive Session (continued)

SELECT - (1) ANOTHER SPEED GROUP
(2) QUIT

1

ENTER LOWEST SPEED (RPM)

9000.0

ENTER HIGHEST SPEED (RPM)

12000.0

ENTER NUMBER OF SPEED POINTS (NOT MORE THAN 11)

SELECT - (1) ANOTHER SPEED GROUP
(2) QUIT

2

SAMPLE 3

RETRIEVAL FILE NO PJ-05-1
 FILE SIZE = 17
 L/D = 0.5000
 ALFA = 1.1250

TABULATION OF BEARING DATA

L (IN)	DIA (IN)	C (IN)	VISC (CP)	W (LBS)	SPEED RANGE (RPM)	PTS
1.0000	1.5000	0.001000	4.0000 01	750.00	6000.00 TO 9000.00	11

LOAD PARAMETER IS ADJUSTED FOR L/D = 0.6667

RPM	ECC (IN)	ATT ANGLE	FRIC (HP)	Q-REQ (GPM)	Q-LOST (GPM)
6.00000 03	3.41710-04	6.88050 01	8.60800-04	8 00480-02	3.82000-02
6.24830 03	3.32320-04	6.94020 01	9.32570-04	8.28270-02	3.86850-02
6.50680 03	3.23020-04	6.99940 01	1.01050-03	8.57050-02	3.91560-02
6.77610 03	3.13830-04	7.05820 01	1.09510-03	8.86860-02	3.96140-02
7.05650 03	3.04760-04	7.11640 01	1.18710-03	9.17750-02	4.00590-02
7.34850 03	2.95810-04	7.17410 01	1.28690-03	9.49760-02	4.04890-02
7.65250 03	2.86980-04	7.23120 01	1.39530-03	9.82940-02	4.09050-02
7.96920 03	2.78290-04	7.28730 01	1.51300-03	1.01730-01	4.13050-02
8.29900 03	2.69720-04	7.34250 01	1.64100-03	1.05300-01	4.16880-02
8.64240 03	2.61280-04	7.39660 01	1.77990-03	1.08990-01	4.20540-02
9.00000 03	2.52980-04	7.44940 01	1.93090-03	1.12830-0	4.24020-02

LOAD AND DYNAMIC COEFFICIENTS ARE ADJUSTED FOR L/D = 0.6667

RPM	K-XX	B-XX	K-XY	B-XY	K-YX	B-YX	K-YY	B-YY
6.0000 03	1.1640 06	8.7600 03	3.0010 06	2.8540 03-1	74.0 06	2.8540 06	1.5660 03	6.2190 03
6.2480 03	1.1420 06	8.5480 03	3.0400 06	2.7370 03-1	8220 06	2.7370 06	1.5690 03	6.1410 03
6.5070 03	1.1220 06	8.3500 03	3.0820 06	2.6250 03-1	8990 06	2.6250 06	1.5720 03	6.0660 03
6.7760 03	1.1020 06	8.1630 03	3.1280 06	2.5170 03-1	9800 06	2.5170 06	1.5740 03	5.9930 03
7.0560 03	1.0840 06	7.9890 03	3.1770 06	2.4140 03-2	0640 06	2.4140 03	1.5760 06	5.9230 03
7.3480 03	1.0660 06	7.8240 03	3.2300 06	2.3150 03-2	1500 06	2.3150 03	1.5790 06	5.8560 03
7.6530 03	1.0490 06	7.6710 03	3.2870 06	2.2210 03-2	2410 06	2.2210 03	1.5810 06	5.7920 03
7.9690 03	1.0320 06	7.5260 03	3.3480 06	2.1310 03-2	3350 06	2.1310 03	1.5830 06	5.7300 03
8.2990 03	1.0170 06	7.3920 03	3.4130 06	2.0440 03-2	4320 06	2.0440 03	1.5850 06	5.6710 03
8.6420 03	1.0020 06	7.2650 03	3.4830 06	1.9620 03-2	5340 06	1.9620 03	1.5870 06	5.6160 03
9.0000 03	9.8870 05	7.1480 03	3.5580 06	1.8840 03-2	6390 06	1.8840 03	1.5880 06	5.5630 03

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Sample 3 - Tabulation of Bearing Data (continued)

*****SYNCH BRG CHARACTERISTICS*****										STABILITY		PARAMETERS	
RPM	KIN	STIFF	MIN DAMP	MAJ DAMP	STIFF	MAJ DAMP	CR MASS	F	PATIO				
9.00000	03	1.04650	06	8.02640-01	1.68360	06	2.29630	00	1.04740	04	5.35420-01		
6.24830	03	1.05490	06	8.23900-01	1.65660	06	2.37640	00	1.04950	04	5.35680-01		
6.50680	03	1.06320	06	8.45970-01	1.63040	06	2.46060	00	1.05160	04	5.35920-01		
6.77610	03	1.07140	06	8.68880-01	1.60520	06	2.54920	00	1.05350	04	5.36180-01		
7.05650	03	1.07950	06	8.92720-01	1.58060	06	2.64230	00	1.05540	04	5.36410-01		
7.34850	03	1.08750	06	9.17420-01	1.55700	06	2.74010	00	1.05710	04	5.36680-01		
7.65250	03	1.09530	06	9.43110-01	1.53420	06	2.84270	00	1.05860	04	5.36950-01		
7.96920	03	1.10290	06	9.69890-01	1.51230	06	2.95030	00	1.06000	04	5.37220-01		
8.29900	03	1.11040	06	9.97860-01	1.49130	06	3.06310	00	1.06140	04	5.37480-01		
8.64240	03	1.11770	06	1.02710	1.47140	06	3.18130	00	1.06270	04	5.37720-01		
9.00000	03	1.12470	06	1.05770	1.45240	06	3.30510	00	1.06410	04	5.37940-01		

LOAD PARAMETER IS ADJUSTED FOR L/D = 0.6667

RPM	ECC(IN)	ATT ANGLE	FRICT(HP)	Q-REQ(GPM)	Q-LOST(GPM)
9.00000	03	2.52980-04	7.44940	01	1.12830-01
9.26270	03	2.47180-04	7.48600	01	1.15630-01
9.53300	03	2.41450-04	7.52190	01	1.18510-01
9.81120	03	2.35800-04	7.55700	01	1.21460-01
1.00980	04	2.30220-04	7.59140	01	1.24490-01
1.03920	04	2.24720-04	7.62490	01	1.27600-01
1.06960	04	2.19300-04	7.65750	01	1.30790-01
1.10080	04	2.13960-04	7.68930	01	1.34070-01
1.13290	04	2.08700-04	7.72020	01	1.37430-01
1.16600	04	2.03520-04	7.75020	01	1.40880-01
1.20000	04	1.98430-04	7.77930	01	1.44420-01

Sample 3 - Tabulation of Bearing Data (continued)

LOAD AND DYNAMIC COEFFICIENTS ARE ADJUSTED FOR L/D = 0.6667

RPM	K-XX	B-XX	K-XY	B-XY	K-YX	B-YX	K-YY	B-YY
9.0000	03 9.8870	05 7.1480	03 3.5580	06 1.8840	03-2.6390	06 1.8840	03 1.5880	06 5.5630
9.2630	03 9.7960	05 7.0690	03 3.6140	06 1.8310	03-2.7170	06 1.8310	03 1.5900	06 5.5280
9.5330	03 9.7090	05 6.9940	03 3.6720	06 1.7790	03-2.7960	06 1.7790	03 1.5910	06 5.4940
9.8110	03 9.6260	05 6.9230	03 3.7330	06 1.7290	03-2.8780	06 1.7290	03 1.5920	06 5.4620
1.0100	04 9.5480	05 6.8550	03 3.7970	06 1.6810	03-2.9620	06 1.6810	03 1.5920	06 5.4310
1.0390	04 9.4740	05 6.7900	03 3.8640	06 1.6350	03-3.0490	06 1.6350	03 1.5930	06 5.4020
1.0700	04 9.4040	05 6.7290	03 3.9340	06 1.5900	03-3.1380	06 1.5900	03 1.5940	06 5.3750
1.1010	04 9.3380	05 6.6710	03 4.0060	06 1.5470	03-3.2300	06 1.5470	03 1.5950	06 5.3490
1.1330	04 9.2760	05 6.6160	03 4.0820	06 1.5050	03-3.3240	06 1.5050	03 1.5960	06 5.3250
1.1660	04 9.2180	05 6.5630	03 4.1610	06 1.4650	03-3.4210	06 1.4650	03 1.5960	06 5.3020
1.2000	04 9.1640	05 6.5130	03 4.2430	06 1.4260	03-3.5210	06 1.4260	03 1.5970	06 5.2800

*****SYNCH BRG CHARACTERISTICS*****									
RPM	MIN	STIFF	MIN	DAMP	MAJ	STIFF	MAJ	DAMP	
9.0000	03 1.12470	06 1.05770	00 1.45240	06 3.30510	00 1.06410	04 5.37940	-01		
9.26270	03 1.12960	06 1.08030	00 1.43950	06 3.39630	00 1.06500	04 5.38090	-01		
9.53300	03 1.13430	06 1.10380	00 1.42710	06 3.49050	00 1.06600	04 5.38220	-01		
9.81120	03 1.13900	06 1.12800	00 1.41520	06 3.58770	00 1.06690	04 5.38330	-01		
1.00980	04 1.14350	06 1.15310	00 1.40380	06 3.68800	00 1.06790	04 5.38430	-01		
1.03920	04 1.14780	06 1.17910	00 1.39290	06 3.79150	00 1.06900	04 5.38510	-01		
1.06960	04 1.15210	06 1.20610	00 1.38250	06 3.89810	00 1.07000	04 5.38570	-01		
1.10080	04 1.15620	06 1.23400	00 1.37250	06 4.00820	00 1.07110	04 5.38620	-01		
1.13290	04 1.16020	06 1.26300	00 1.36300	06 4.12160	00 1.07230	04 5.38640	-01		
1.16600	04 1.16400	06 1.29290	00 1.35400	06 4.23820	00 1.07330	04 5.38690	-01		
1.20000	04 1.16770	06 1.32400	00 1.34530	06 4.35870	00 1.07450	04 5.38680	-01		

STABILITY PARAMETERS
CR MASS F RATIO

SAMPLE 3

DATA LINES IN RSVP FORMAT

1.1640	06	8.7600	03	3.0010	06	2.8540	03-1.7470	06	2.8540	03	1.5660	06	6.2190	03
1.1420	06	8.5480	03	3.0400	06	2.7370	03-1.8220	06	2.7370	03	1.5690	06	6.1410	03
1.1220	06	8.3500	03	3.0820	06	2.6250	03-1.8990	06	2.6250	03	1.5720	06	6.0660	03
1.1020	06	8.1630	03	3.1280	06	2.5170	03-1.9800	06	2.5170	03	1.5740	06	5.9930	03
1.0840	06	7.9890	03	3.1770	06	2.4140	03-2.0640	06	2.4140	03	1.5760	06	5.9230	03
1.0660	06	7.8240	03	3.2300	06	2.3150	03-2.1500	06	2.3150	03	1.5790	06	5.8560	03
1.0490	06	7.6710	03	3.2870	06	2.2210	03-2.2410	06	2.2210	03	1.5810	06	5.7920	03
1.0320	06	7.5260	03	3.3480	06	2.1310	03-2.3350	06	2.1310	03	1.5830	06	5.7300	03
1.0170	06	7.3920	03	3.4130	06	2.0440	03-2.4320	06	2.0440	03	1.5850	06	5.6710	03
1.0020	06	7.2650	03	3.4830	06	1.9620	03-2.5340	06	1.9620	03	1.5870	06	5.6160	03
9.8870	05	7.1480	03	3.5580	06	1.8840	03-2.6390	06	1.8840	03	1.5880	06	5.5630	03
9.8870	05	7.1480	03	3.5580	06	1.8840	03-2.6390	06	1.8840	03	1.5880	06	5.5630	03
9.7960	05	7.0690	03	3.6140	06	1.8310	03-2.7170	06	1.8310	03	1.5900	06	5.5280	03
9.7090	05	6.9940	03	3.6720	06	1.7790	03-2.7960	06	1.7790	03	1.5910	06	5.4940	03
9.6260	05	6.9230	03	3.7330	06	1.7290	03-2.8780	06	1.7290	03	1.5920	06	5.4620	03
9.5480	05	6.8550	03	3.7970	06	1.6810	03-2.9620	06	1.6810	03	1.5920	06	5.4310	03
9.4740	05	6.7900	03	3.8640	06	1.6350	03-3.0490	06	1.6350	03	1.5930	06	5.4020	03
9.4040	05	6.7290	03	3.9340	06	1.5900	03-3.1380	06	1.5900	03	1.5940	06	5.3750	03
9.3380	05	6.6710	03	4.0060	06	1.5470	03-3.2300	06	1.5470	03	1.5950	06	5.3490	03
9.2760	05	6.6160	03	4.0820	06	1.5050	03-3.3240	06	1.5050	03	1.5960	06	5.3250	03
9.2180	05	6.5630	03	4.1610	06	1.4650	03-3.4210	06	1.4650	03	1.5960	06	5.3020	03
9.1640	05	6.5130	03	4.2430	06	1.4260	03-3.5210	06	1.4260	03	1.5970	06	5.2800	03

SAMPLE 4

RECORD OF INTERACTIVE SESSION

ENTER DATA TABLE NAME: PJ-05-1
ENTER OUTPUT FILE NAME: OUTPUT

SELECT: (1) PREPARE DATA FOR RSVP INPUT
(2) DIMENSIONAL TABLE
(3) DIMENSIONLESS TABLE
(4) QUIT

1

SELECT: (1) SYNCH FREQ, OR
(2) ASYNCH FREQ?

1

ENTER BEARING LENGTH (IN)

1.0

ENTER BEARING DIAMETER (IN)

1.5

ENTER BEARING CLEARANCE (IN)

0.001

ENTER VISCOSITY (CENTI-POISE)

40.0

ENTER BEARING LOAD (LBS)

750.0

ENTER BEARING COEFS FILE NAME: RSVP

SELECT: (1) USE DEFAULT L/D = 0.5000
(2) ADJUST DATA FOR L/D = 0.6667

2

SELECT: (1) LOAD VECTOR IN VERTICAL PLANE, OR
(2) INCLINED LOAD VECTOR?

2

ENTER LOAD INCLINATION ANGLE (DEG)?

30.0

SELECT: (1) RIGID FOUNDATION
(2) ISOTROPIC FOUNDATION COMPLIANCE, OR
(3) ANISOTROPIC FOUNDATION COMPLIANCE?

1

ENTER LOWEST SPEED (RPM)

6000.0

ENTER HIGHEST SPEED (RPM)

9000.0

ENTER NUMBER OF SPEED POINTS (NOT MORE THAN 11)

11

SELECT - (1) ANOTHER SPEED GROUP
(2) QUIT

1

ENTER LOWEST SPEED (RPM)

9000.0

ENTER HIGHEST SPEED (RPM)

12000.0

ENTER NUMBER OF SPEED POINTS (NOT MORE THAN 11)

Sample 4 - Record of Interactive Session (continued)

11

SELECT - (1) ANOTHER SPEED GROUP
(2) QUIT

1

ENTER LOWEST SPEED (RPM)

12000.0

ENTER HIGHEST SPEED (RPM)

15000.0

ENTER NUMBER OF SPEED POINTS (NOT MORE THAN 11)

5

SELECT - (1) ANOTHER SPEED GROUP
(2) QUIT

2

RETRIEVAL FILE NO PJ-05-1

FILE SIZE = 17

L'0 = 0 5000

ALFA = 1 1250

SAMPLE 4

TABULATION OF PEARING DATA

L (IN)	DIA (IN)	C (IN)	VISC (CP)	W (LES)	SPEED RANGE (RPM)	PTS
1 0000	1.5000	0 001000	4 0000 01	750 00	6000 00 TO 9000 00	11

LOAD PARAMETER IS ADJUSTED FOR L/D = 0 6667

RPM	ECC (IN)	ATT ANGLE	FPICT (HP)	O-REP (GPM)	O-LOST (GPM)
6 00000 02	3 41710-04	6 88050 01	8 60800-04	8 00480-02	3 82000-02
6 24830 03	3 32320-04	6 94020 01	9 32570-04	8 28270-02	3 86850-02
6 50680 03	3 23020-04	6 99340 01	1 01050-03	8 57050-02	3 91560-02
6 77610 03	3 13830-04	7 05820 01	1 09510-03	8 86860-02	3 96140-02
7 05650 03	3 04760-04	7 11640 01	1 18710-03	9 17750-02	4 00590-02
7 34850 03	2 95810-04	7 17410 01	1 28690-03	9 49760-02	4 04890-02
7 65250 03	2 86980-04	7 23120 01	1 39530-03	9 82940-02	4 09050-02
7 96620 03	2 78290-04	7 28730 01	1 51300-03	1 01730-01	4 13050-02
8 29900 03	2 69720-04	7 34250 01	1 64100-03	1 05300-01	4 16880-02
8 64240 03	2 61280-04	7 39660 01	1 77990-03	1 08990-01	4 20540-02
9 00000 03	2 52980-04	7 44940 01	1 93090-03	1 12830-01	4 24020-02

LOAD AND DYNAMIC COEFFICIENTS ARE ADJUSTED FOR L/D = 0 6667

RPM	K-XX	B-XX	K-XY	B-XY	K-YZ	B-YZ	K-VY	B-VY
6 0000 03	7 2130 05	5 6530 03	2 5130 06	2 5770 03-2	2350 06	2 5270 03	2 0090 06	9 3260 03
6 2480 03	7 2160 05	5 5760 03	2 5510 06	2 4110 03-2	3110 06	2 4110 03	1 9900 06	9 1130 03
6 5070 03	7 2220 05	5 5060 03	2 5920 06	2 3010 03-2	3900 06	2 3010 03	1 9710 06	8 9100 03
6 7760 03	7 2330 05	5 4410 03	2 6360 06	2 1980 03-2	4710 06	2 1980 03	1 9530 06	8 7160 03
7 0560 03	7 2480 05	5 3820 03	2 6850 06	2 1010 03-2	5550 06	2 1010 03	1 9350 06	8 5310 03
7 3480 03	7 2660 05	5 3270 03	2 7380 06	2 0100 03-2	6420 06	2 0100 03	1 9180 06	8 3530 03
7 6530 03	7 2880 05	5 2770 03	2 7950 06	2 9240 03-2	7230 06	2 9240 03	1 9010 06	8 1850 03
7 9690 03	7 3130 05	5 2320 03	2 8560 06	2 8430 03-2	8260 06	2 8430 03	1 8840 06	8 0240 03
8 2990 03	7 3410 05	5 1910 03	2 9220 06	2 7670 03-2	9230 06	2 7670 03	1 8690 06	7 8720 03
8 6420 03	7 3740 05	5 1540 03	2 9930 06	2 6950 03-3	10240 06	2 6950 03	1 8520 06	7 7270 03
9 0000 03	7 4090 05	5 1200 03	3 0680 06	2 6280 03-3	1280 06	2 6280 03	1 8360 06	7 5910 03

(Page 1 of 4)

Sample 4 - Tabulation of Bearing Data (continued)

*****SYNCH BRG CHARACTERISTICS*****										STABILITY		PARAMETERS	
RPM	MIN	STIFF	MIN	DAMP	MAJ	STIFF	MAJ	DAMP	CR	MASS	F	RATIO	
6.00000	03	1.0465D	06	8.0264D-01	1.6836D	06	2.2963D	00	1.0474D	04	5.3542D-01		
6.2483D	03	1.0549D	06	8.2390D-01	1.6566D	06	2.3764D	00	1.0495D	04	5.3568D-01		
6.5068D	03	1.0632D	06	8.4597D-01	1.6304D	06	2.4606D	00	1.0516D	04	5.3592D-01		
6.7761D	03	1.0714D	06	8.6898D-01	1.6052D	06	2.5492D	00	1.0535D	04	5.3618D-01		
7.0565D	03	1.0795D	06	8.9272D-01	1.5806D	06	2.6423D	00	1.0554D	04	5.3641D-01		
7.3485D	03	1.0875D	06	9.1742D-01	1.5570D	06	2.7401D	00	1.0571D	04	5.3668D-01		
7.6525D	03	1.0953D	06	9.4311D-01	1.5342D	06	2.8427D	00	1.0586D	04	5.3695D-01		
7.9692D	03	1.1029D	06	9.6989D-01	1.5123D	06	2.9503D	00	1.0600D	04	5.3722D-01		
8.2990D	03	1.1104D	06	9.9786D-01	1.4913D	06	3.0631D	00	1.0614D	04	5.3748D-01		
8.6424D	03	1.1177D	06	1.0271D 00	1.4714D	06	3.1813D	00	1.0627D	04	5.3772D-01		
9.0000D	03	1.1247D	06	1.0577D 00	1.4524D	06	3.3051D	00	1.0641D	04	5.3794D-01		

LOAD PARAMETER IS ADJUSTED FOR L/D = 0.6667

RPM	ECC(IN)	ATT	ANGLE	FRICT(HP)	A-REQ(GPM)	Q-LOST(GPM)
9.0000D	03	2.5298D-04	7.4494D 01	1.9309D-03	1.1283D-01	4.2402D-02
9.2627D	03	2.4718D-04	7.4860D 01	2.0459D-03	1.1563D-01	4.2638D-02
9.5330D	03	2.4145D-04	7.5219D 01	2.1679D-03	1.1851D-01	4.2864D-02
9.8112D	03	2.3580D-04	7.5570D 01	2.2973D-03	1.2146D-01	4.3081D-02
1.0098D	04	2.3022D-04	7.5914D 01	2.4345D-03	1.2449D-01	4.3288D-02
1.0392D	04	2.2472D-04	7.6249D 01	2.5801D-03	1.2760D-01	4.3486D-02
1.0696D	04	2.1930D-04	7.6575D 01	2.7346D-03	1.3079D-01	4.3674D-02
1.1008D	04	2.1396D-04	7.6893D 01	2.8985D-03	1.3407D-01	4.3853D-02
1.1329D	04	2.0870D-04	7.7202D 01	3.0723D-03	1.3743D-01	4.4022D-02
1.1660D	04	2.0352D-04	7.7502D 01	3.2567D-03	1.4088D-01	4.4183D-02
1.2000D	04	1.9843D-04	7.7793D 01	3.4524D-03	1.4442D-01	4.4334D-02

Sample 4 - Tabulation of Bearing Data (continued)

LOAD AND DYNAMIC COEFFICIENTS ARE ADJUSTED FOR L/D = 0.6667												
RPM	K-XX	B-XX	K-XY	B-XY	K-YX	B-YX	K-YY	B-YY				
9.0000	03 7.4090	05 5.1200	03 3.0680	06 1.6280	03-3 1280	06 1.6280	03 1.8360	06 7.5910				
9.2630	03 7.4360	05 5.0980	03 3.1250	06 1.5830	03-3 2050	06 1.5830	03 1.8250	06 7.4980				
9.5330	03 7.4650	05 5.0700	03 3.1850	06 1.5390	03-3 2830	06 1.5390	03 1.8150	06 7.4100				
9.8110	03 7.4950	05 5.0600	03 3.2470	06 1.4970	03-3 3640	06 1.4970	03 1.8050	06 7.3250				
1.0100	04 7.5260	05 5.0430	03 3.3120	06 1.4570	03-3 4470	06 1.4570	03 1.7950	06 7.2430				
1.0390	04 7.5590	05 5.0270	03 3.3800	06 1.4180	03-3 5320	06 1.4180	03 1.7850	06 7.1650				
1.0700	04 7.5930	05 5.0130	03 3.4520	06 1.3810	03-3 6200	06 1.3810	03 1.7750	06 7.0910				
1.1010	04 7.6280	05 5.0010	03 3.5260	06 1.3460	03-3 7100	06 1.3460	03 1.7660	06 7.0190				
1.1330	04 7.6640	05 4.9890	03 3.6030	06 1.3120	03-3 8030	06 1.3120	03 1.7570	06 6.9510				
1.1660	04 7.7000	05 4.9790	03 3.6840	06 1.2790	03-3 8980	06 1.2790	03 1.7480	06 6.8850				
1.2000	04 7.7380	05 4.9700	03 3.7680	06 1.2470	03-3 9960	06 1.2470	03 1.7390	06 6.8230				

*****SYNCH BRG CHARACTERISTICS*****												
RPM	MIN	STIFF	MIN	DAMP	MAJ	STIFF	MAJ	DAMP				
9.0000	03 1.12470	06 1.05770	00 1.45240	06 3.30510	00 1.06410	04 5.37940	01 1.06500	04 5.38090				
9.26270	03 1.12960	06 1.08030	00 1.43950	06 3.39630	00 1.06600	04 5.38220	01 1.06690	04 5.38330				
9.53300	03 1.13430	06 1.10380	00 1.42710	06 3.49050	00 1.06790	04 5.38430	01 1.06900	04 5.38510				
9.81120	03 1.13900	06 1.12800	00 1.40380	06 3.68800	00 1.07000	04 5.38570	01 1.07110	04 5.38620				
1.00980	04 1.14350	06 1.15310	00 1.39290	06 3.79150	00 1.07230	04 5.38640	01 1.07330	04 5.38690				
1.03920	04 1.14780	06 1.17910	00 1.38250	06 3.89810	00 1.07450	04 5.38680	01 1.07570	04 5.38730				
1.06960	04 1.15210	06 1.20610	00 1.37250	06 4.00820	00 1.07690	04 5.38770	01 1.07810	04 5.38820				
1.10080	04 1.15620	06 1.23400	00 1.36300	06 4.12160	00 1.07930	04 5.38860	01 1.08050	04 5.38910				
1.13290	04 1.16020	06 1.26300	00 1.35400	06 4.23820	00 1.08170	04 5.38950	01 1.08290	04 5.39000				
1.16600	04 1.16400	06 1.29290	00 1.34530	06 4.35870	00 1.08400	04 5.39090	01 1.08520	04 5.39140				
1.20000	04 1.16770	06 1.32400	00 1.33660	06 4.48020	00 1.08530	04 5.39180	01 1.08650	04 5.39230				

STABILITY PARAMETERS
CF MASS F RATIO

Sample 4 - Tabulation of Bearing Data (continued)

L (IN)	DIA (IN)	C (IN)	VISC (CP)	W (LBS)	SPEED RANGE (RPM)	PTS
1.0000	1.5000	0.001000	4.0000 01	750 00	12000 00 TO 15000.00	5

LOAD PARAMETER IS ADJUSTED FOR L/D = 0.6667

RPM	ECC (IN)	ATT ANGLE	FRICT (HP)	Q-REQ (GPM)	Q-LOST (GPM)
1 20000 04	1.98430-04	7.77930 01	3.45240-03	1 44420-01	4.43340-02
1 26880 04	1.88820-04	7.83360 01	3.86640-03	1.51560-01	4.46050-02
1 34160 04	1.79570-04	7.88570 01	4.33040-03	1 59090-01	4.48520-02
1 41860 04	1 70700-04	7.93610 01	4.85050-03	1.67030-01	4.50790-02
1 50000 04	1.62200-04	7 98530 01	5 43320-03	1 75420-01	4 52910-02

LOAD AND DYNAMIC COEFFICIENTS ARE ADJUSTED FOR L/D = 0.6667

RPM	K-XX	B-XX	K-XY	B-XY	K-YX	B-YX	K-YY	B-YY
1 2000 04	7.7380 05	4.9700 03	3.7680 06	1.2470 03-3	3.9960 06	1.2470 03	1.7390 06	6.8230 03
1 2690 04	7 8110 05	4.9560 03	3 9400 06	1.1890 03-4	1940 06	1.1890 03	1.7230 06	6.7090 03
1 3420 04	7.8840 05	4 9450 03	4.1260 06	1.1360 03-4	4040 06	1 1360 03	1.7070 06	6.6040 03
1 4190 04	7 9560 05	4.9370 03	4.3250 06	1.0870 03-4	6260 06	1.0870 03	1.6930 06	6.5050 03
1 5000 04	8.0240 05	4.9310 03	4.5390 06	1 0430 03-4	8610 06	1.0430 03	1.6780 06	6.4120 03

PPM	MIN	STIFF	MIN	DAMP	MAX	STIFF	MAX	DAMP	CP	MASS	F	PATIO
1 20000 04	1.16770 06	1.32400 00	1.34530 06	4 35870 00	1.07450 04	5.38680-01						
1 26880 04	1.17460 06	1.38750 00	1.32960 06	4.60320 00	1 07680 04	5.38640-01						
1 34160 04	1.18090 06	1.45490 00	1.31500 06	4.86290 00	1 07880 04	5 38620-01						
1 41860 04	1.18680 06	1.52640 00	1.30130 06	5.13920 00	1.08040 04	5.38650-01						
1 50000 04	1.19220 06	1.60180 00	1.28830 06	5 43300 00	1 08140 04	5.38760-01						

SAMPLE 4

DATA LINES IN RSVP FORMAT

7.2130	05	5.6530	03	2.5130	06	2.5270	03-2.2350	06	2.5270	03	2.0090	06	9.3260	03
7.2160	05	5.5760	03	2.5510	06	2.4110	03-2.3110	06	2.4110	03	1.9900	06	9.1130	03
7.2220	05	5.5060	03	2.5920	06	2.3010	03-2.3900	06	2.3010	03	1.9710	06	8.9100	03
7.2330	05	5.4410	03	2.6360	06	2.1980	03-2.4710	06	2.1980	03	1.9530	06	8.7160	03
7.2480	05	5.3820	03	2.6850	06	2.1010	03-2.5550	06	2.1010	03	1.9350	06	8.5310	03
7.2660	05	5.3270	03	2.7380	06	2.0100	03-2.6420	06	2.0100	03	1.9180	06	8.3530	03
7.2880	05	5.2770	03	2.7950	06	1.9240	03-2.7330	06	1.9240	03	1.9010	06	8.1850	03
7.3130	05	5.2320	03	2.8560	06	1.8430	03-2.8260	06	1.8430	03	1.8840	06	8.0240	03
7.3410	05	5.1910	03	2.9220	06	1.7670	03-2.9230	06	1.7670	03	1.8680	06	7.8720	03
7.3740	05	5.1540	03	2.9930	06	1.6950	03-3.0240	06	1.6950	03	1.8520	06	7.7270	03
7.4090	05	5.1200	03	3.0680	06	1.6280	03-3.1280	06	1.6280	03	1.8360	06	7.5910	03
7.4090	05	5.1200	03	3.0680	06	1.6280	03-3.1280	06	1.6280	03	1.8360	06	7.5910	03
7.4360	05	5.0980	03	3.1250	06	1.5830	03-3.2050	06	1.5830	03	1.8250	06	7.4980	03
7.4650	05	5.0780	03	3.1850	06	1.5390	03-3.2330	06	1.5390	03	1.8150	06	7.4100	03
7.4950	05	5.0600	03	3.2470	06	1.4970	03-3.3640	06	1.4970	03	1.8050	06	7.3250	03
7.5260	05	5.0430	03	3.3120	06	1.4570	03-3.4470	06	1.4570	03	1.7950	06	7.2430	03
7.5590	05	5.0270	03	3.3800	06	1.4180	03-3.5320	06	1.4180	03	1.7850	06	7.1650	03
7.5930	05	5.0130	03	3.4520	06	1.3810	03-3.6200	06	1.3810	03	1.7750	06	7.0910	03
7.6280	05	5.0010	03	3.5260	06	1.3460	03-3.7100	06	1.3460	03	1.7660	06	7.0190	03
7.6640	05	4.9890	03	3.6030	06	1.3120	03-3.8030	06	1.3120	03	1.7570	06	6.9510	03
7.7000	05	4.9790	03	3.6840	06	1.2790	03-3.8980	06	1.2790	03	1.7480	06	6.8850	03
7.7380	05	4.9700	03	3.7680	06	1.2470	03-3.9960	06	1.2470	03	1.7390	06	6.8230	03
7.7380	05	4.9700	03	3.7680	06	1.2470	03-3.9960	06	1.2470	03	1.7390	06	6.8230	03
7.8110	05	4.9560	03	3.9400	06	1.1890	03-4.1940	06	1.1890	03	1.7230	06	6.7090	03
7.8840	05	4.9450	03	4.1260	06	1.1360	03-4.4040	06	1.1360	03	1.7070	06	6.6040	03
7.9560	05	4.9370	03	4.3250	06	1.0870	03-4.6260	06	1.0870	03	1.6930	06	6.5050	03
8.0240	05	4.9310	03	4.5380	06	1.0430	03-4.8610	06	1.0430	03	1.6780	06	6.4120	03

SAMPLE 5

RECORD OF INTERACTIVE SESSION

ENTER DATA TABLE NAME: PJ-05-1
 ENTER OUTPUT FILE NAME: OUTPUT

SELECT: (1) PREPARE DATA FOR RSVP INPUT
 (2) DIMENSIONAL TABLE
 (3) DIMENSIONLESS TABLE
 (4) QUIT

SELECT: (1) SYNCH FREQ, OR
 (2) ASYNCH FREQ?

2
 ENTER NUMBER OF FREQ GROUPS?

2
 ENTER BEARING LENGTH (IN)

1 0

ENTER BEARING DIAMETER (IN)

2.0

ENTER BEARING CLEARANCE (IN)

0.001

ENTER VISCOSITY (CENTI-POISE)

40.0

ENTER BEARING LOAD (LBS)

800.0

ENTER BEARING COEFS FILE NAME: RSVP

SELECT: (1) LOAD VECTOR IN VERTICAL PLANE, OR
 (2) INCLINED LOAD VECTOR?

1

SELECT: (1) RIGID FOUNDATION
 (2) ISOTROPIC FOUNDATION COMPLIANCE, OR
 (3) ANISOTROPIC FOUNDATION COMPLIANCE?

1

ENTER LOWEST SPEED (RPM)

7500.0

ENTER HIGHEST SPEED (RPM)

7500.0

ENTER NUMBER OF SPEED POINTS (NOT MORE THAN 11)

1

ENTER FREQ DATA (HZ) FOR FREQ GROUP 1 AT 7.50000 03 RPM
 LOWEST FREQ?

25.0

HIGHEST FREQ?

50.0

NUMBER OF FREQ POINTS?

11

ENTER FREQ DATA (HZ) FOR FREQ GROUP 2 AT 7.50000 03 RPM
 LOWEST FREQ?

50.0

HIGHEST FREQ?

100.0

LOWEST FREQ?

50.0

HIGHEST FREQ?

100.0

NUMBER OF FREQ POINTS?

11

SELECT - (1) ANOTHER SPEED GROUP
 (2) QUIT

2

RETRIEVAL FILE NO PJ-05-1

FILE SIZE = 17

L/D = 0.5000

ALFA = 1.1250

SAMPLE 5

TABULATION OF BEARING DATA

L (IN)	DIA (IN)	C (IN)	VISC (CP)	W (LBS)	SPEED RANGE (RPM)	PTS
1.0000	2.0000	0.001000	4.0000 01	800.00	7500.00 TO 7500.00	1

RPM	ECC (IN)	ATT ANGLE	FRICT (HP)	Q-REQ (GPM)	Q-LOST (GPM)
7.50000 03	2.28450-04	7.60220 01	3.18410-03	1.23130-01	4.25400-02

RPM = 7.5000 03	B-XX	K-XX	B-XY	K-XY	B-YY	K-YY
FREQ	5.0000 01	1.0160 06	9.9050 03	4.0730 06	2.4150 03	1.6990 06
						7.8590 03

ASYNCHRONOUS BEARING CHARACTERISTICS

*****MINOR MODE*****										*****MAJOR MODE*****									
FREQUENCY	STIFFNESS	CR DAMP	ELLIPTIC	ORIENT	STIFFNESS	CR DAMP	ELLIPTIC	ORIENT		STIFFNESS	CR DAMP	ELLIPTIC	ORIENT						
5.0000 01	1.2960 06	3.4380-01	8.8790-01	1.4280 02	1.4190 06	2.2810 00	6.9040-01	2.7860 01											
5.3590 01	1.2920 06	2.7280-01	8.7660-01	1.4060 02	1.4230 06	2.3490 00	6.7970-01	2.8130 01											
5.7430 01	1.2880 06	1.9650-01	8.6420-01	1.3860 02	1.4270 06	2.4230 00	6.6840-01	2.8390 01											
6.1560 01	1.2830 06	1.1450-01	8.5060-01	1.3690 02	1.4320 06	2.5020 00	6.5650-01	2.8640 01											
6.5980 01	1.2780 06	2.6550-02	8.3590-01	1.3550 02	1.4370 06	2.5860 00	6.4410-01	2.8900 01											
7.0710 01	1.2730 06	6.7920-02	8.2020-01	1.3420 02	1.4420 06	2.6770 00	6.3110-01	2.9140 01											
7.5790 01	1.2670 06	1.5940-01	8.0350-01	1.3310 02	1.4470 06	2.7740 00	6.1750-01	2.9390 01											
8.1230 01	1.2620 06	2.7830-01	7.8590-01	1.3210 02	1.4530 06	2.8780 00	6.0340-01	2.9620 01											
8.7060 01	1.2560 06	3.9530-01	7.6740-01	1.3120 02	1.4590 06	2.9890 00	5.8870-01	2.9860 01											
9.3300 01	1.2500 06	5.2100-01	7.4810-01	1.3040 02	1.4650 06	3.1090 00	5.7350-01	3.0080 01											
1.0000 02	1.2430 06	6.5590-01	7.2810-01	1.2970 02	1.4720 06	3.2380 00	5.5780-01	3.0300 01											

Sample 5 - Tabulation of Bearing Data (continued)

RPM = 7.5000 03
 FREQ K-XX B-XX K-XY K-YY B-YY K-YY B-YY
 2.5000 01 1.0160 06 9.9050 03 4.0730 06 2 4150 03-3.1890 06 2.4150 03 1.6990 06 7 8590 03

ASYNCHRONOUS BEARING CHARACTERISTICS
 *****MINOR MODE*****
 FREQUENCY STIFFNESS CR DAMP ELLIPTIC ORIENT
 2.5000 01 1.3260 06-8.3560-01 9.2460-01 1.7600 02 1.3890 06 1.8030 00-7.7030-01 2.5180 01
 2.6790 01 1.3240 06-8.0050-01 9.2620-01 1.7310 02 1.3910 06 1.8370 00-7.6430-01 2.5440 01
 2.8720 01 1.3220 06-7.6280-01 9.2720-01 1.6980 02 1.3930 06 1.8740 00-7.5790-01 2.5710 01
 3.0780 01 1.3190 06-7.2240-01 9.2710-01 1.6620 02 1.3960 06 1.9130 00-7.5110-01 2.5980 01
 3.2990 01 1.3160 06-6.7910-01 9.2580-01 1.6250 02 1.3980 06 1.9560 00-7.4390-01 2.6250 01
 3.5360 01 1.3140 06-6.3260-01 9.2320-01 1.5870 02 1.4010 06 2.0010 00-7.3620-01 2.6520 01
 3.7890 01 1.3100 06-5.8270-01 9.1920-01 1.5500 02 1.4040 06 2.0500 00-7.2810-01 2.6790 01
 4.0610 01 1.3070 06-5.2920-01 9.1360-01 1.5150 02 1.4080 06 2.1020 00-7.1940-01 2.7060 01
 4.3530 01 1.3040 06-4.7170-01 9.0640-01 1.4830 02 1.4110 06 2.1570 00-7.1030-01 2.7330 01
 4.6650 01 1.3000 06-4.1000-01 8.9790-01 1.4540 02 1.4150 06 2.2170 00-7.0060-01 2.7600 01
 5.0000 01 1.2960 06-3.4380-01 8.8790-01 1.4280 02 1.4190 06 2.2810 00-6.9040-01 2.7860 01

SAMPLE 5

DATA LINES IN RSVP FORMAT

1.0160 06 9.9050 03 4.0730 06 2.4150 03-3.1890 06 2.4150 03 1.6990 06 7.8590 03
1.0160 06 9.9050 03 4.0730 06 2.4150 03-3.1890 06 2.4150 03 1.6990 06 7.8590 03

SAMPLE 6

RECORD OF INTERACTIVE SESSION

ENTER DATA FILE NAME P-05-10
ENTER OUTPUT FILE NAME OUTPUT

SELECT: (1) PREPARE DATA FOR RSVP INPUT
(2) DIMENSIONAL TABLE
(3) DIMENSIONLESS TABLE
(4) QUIT

1
SELECT: (1) SYNCH FREQ. OR
(2) ASYNCH FREQ?

2
ENTER NUMBER OF FREQ GROUPS?

2
ENTER BEARING LENGTH (IN)

1.0

ENTER BEARING DIAMETER (IN)

2.0

ENTER BEARING CLEARANCE (IN)

0.001

ENTER VISCOSITY (CENTI-POISE)

40.0

ENTER BEARING LOAD (LBS)

800.0

ENTER BEARING COEFS FILE NAME: RSVP

SELECT: (1) LOAD VECTOR IN VERTICAL PLANE OR
(2) INCLINED LOAD VECTOR?

1

SELECT: (1) RIGID FOUNDATION
(2) ISOTROPIC FOUNDATION COMPLIANCE OR
(3) ANISOTROPIC FOUNDATION COMPLIANCE

2

SELECT: (1) RADIAL BEARING OR
(2) ANGULAR BEARING?

1

ENTER PEDESTAL WEIGHT (LB)?

0.0

ENTER PEDESTAL STIFFNESS IN VERTICAL PLANE
(LB/IN) FOR RADIAL BRG, OR (IN-LB/RAD) FOR ANG BRG

1.00+05

ENTER PEDESTAL DAMPING IN VERTICAL PLANE
(LB-SEC/IN) FOR RAD BRG, OR (IN-LB-SEC/RAD) FOR ANG BRG

0.0

Sample 6 - Record of Interactive Session (continued)

ENTER LOWEST SPEED (RPM)

1500 0

ENTER HIGHEST SPEED (RPM)

2500 0

ENTER NUMBER OF SPEED POINTS (NOT MORE THAN 11)

ENTER FREQ DATA (HZ) FOR FREQ GROUP 1 AT 7 50000 03 RPM
LOWEST FREQ?

10 0

HIGHEST FREQ?

50 0

NUMBER OF FREQ POINTS?

11

ENTER FREQ DATA (HZ) FOR FREQ GROUP 2 AT 7 50000 03 RPM
LOWEST FREQ?

10 0

HIGHEST FREQ?

100 0

NUMBER OF FREQ POINTS?

11

SELECT - (1) ANOTHER SPEED GROUP
(2) QUIT

[illegible]

TABULATION OF BEARING DATA

TIME	ALT (FT)	SPD (KTS)	YAW (DEG)	ROLL (DEG)	PITCH (DEG)	SPEED RANGE (KPH)	ALT (FT)
1000	3000	100	0	0	0	100.00	1000
1005	3000	100	0	0	0	100.00	1000
1010	3000	100	0	0	0	100.00	1000
1015	3000	100	0	0	0	100.00	1000
1020	3000	100	0	0	0	100.00	1000
1025	3000	100	0	0	0	100.00	1000
1030	3000	100	0	0	0	100.00	1000
1035	3000	100	0	0	0	100.00	1000
1040	3000	100	0	0	0	100.00	1000
1045	3000	100	0	0	0	100.00	1000
1050	3000	100	0	0	0	100.00	1000
1055	3000	100	0	0	0	100.00	1000
1100	3000	100	0	0	0	100.00	1000
1105	3000	100	0	0	0	100.00	1000
1110	3000	100	0	0	0	100.00	1000
1115	3000	100	0	0	0	100.00	1000
1120	3000	100	0	0	0	100.00	1000
1125	3000	100	0	0	0	100.00	1000
1130	3000	100	0	0	0	100.00	1000
1135	3000	100	0	0	0	100.00	1000
1140	3000	100	0	0	0	100.00	1000
1145	3000	100	0	0	0	100.00	1000
1150	3000	100	0	0	0	100.00	1000
1155	3000	100	0	0	0	100.00	1000
1200	3000	100	0	0	0	100.00	1000
1205	3000	100	0	0	0	100.00	1000
1210	3000	100	0	0	0	100.00	1000
1215	3000	100	0	0	0	100.00	1000
1220	3000	100	0	0	0	100.00	1000
1225	3000	100	0	0	0	100.00	1000
1230	3000	100	0	0	0	100.00	1000
1235	3000	100	0	0	0	100.00	1000
1240	3000	100	0	0	0	100.00	1000
1245	3000	100	0	0	0	100.00	1000
1250	3000	100	0	0	0	100.00	1000
1255	3000	100	0	0	0	100.00	1000
1300	3000	100	0	0	0	100.00	1000
1305	3000	100	0	0	0	100.00	1000
1310	3000	100	0	0	0	100.00	1000
1315	3000	100	0	0	0	100.00	1000
1320	3000	100	0	0	0	100.00	1000
1325	3000	100	0	0	0	100.00	1000
1330	3000	100	0	0	0	100.00	1000
1335	3000	100	0	0	0	100.00	1000
1340	3000	100	0	0	0	100.00	1000
1345	3000	100	0	0	0	100.00	1000
1350	3000	100	0	0	0	100.00	1000
1355	3000	100	0	0	0	100.00	1000
1400	3000	100	0	0	0	100.00	1000
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Year	1950	1951	1952	1953	1954	1955	1956	1957	1958	1959	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041	2042	2043	2044	2045	2046	2047	2048	2049	2050	2051	2052	2053	2054	2055	2056	2057	2058	2059	2060	2061	2062	2063	2064	2065	2066	2067	2068	2069	2070	2071	2072	2073	2074	2075	2076	2077	2078	2079	2080	2081	2082	2083	2084	2085	2086	2087	2088	2089	2090	2091	2092	2093	2094	2095	2096	2097	2098	2099	2100
1950	1950	1951	1952	1953	1954	1955	1956	1957	1958	1959	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041	2042	2043	2044	2045	2046	2047	2048	2049	2050	2051	2052	2053	2054	2055	2056	2057	2058	2059	2060	2061	2062	2063	2064	2065	2066	2067	2068	2069	2070	2071	2072	2073	2074	2075	2076	2077	2078	2079	2080	2081	2082	2083	2084	2085	2086	2087	2088	2089	2090	2091	2092	2093	2094	2095	2096	2097	2098	2099	2100

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(Page 1 of 2)

Sample 6 - Tabulation of Bearing Data (continued)

RPM = " 5000 HZ									
FREQ	Y-Y	5-X	4-X	B-X	1-Y	B-Y	Y-Y	B-Y	B-Y
5 0000	01 9 7271	04-1 4850	00 2 7310	03-6 4470	01-1 5940	03 8 0030	00 9 7300	04-4 1940	00
5 7500	01 9 7020	04-8 4740	01 3 9160	03-7 2590	00-1 3190	03 8 2540	00 9 6940	04-3 5280	00
5 7430	01 9 6790	04-1 4730	00 2 7840	03-7 8610	00-9 3440	02 8 3660	00 9 6540	04-2 5920	00
6 1500	01 9 6610	04 1 0060	00 2 4270	03-8 5320	00-2 3200	02 8 2190	00 9 6180	04-1 3560	00
6 5980	01 9 6560	04 2 1330	00 1 9000	03-8 5070	00 1 6300	02 7 6910	00 9 5940	04 1 1990	01
7 0710	01 9 6680	04 3 1900	00 1 2510	03-8 2350	00 7 7230	02 6 7220	00 9 5900	04 1 6470	00
7 3790	01 9 7000	04 3 9640	00 5 3020	02-7 4250	00 1 2640	03 5 4430	00 9 6110	04 2 9470	00
8 1230	01 9 7450	04 4 3290	00 4 2450	00-6 3970	00 1 6110	03 4 0560	00 9 6530	04 3 7980	00
8 7060	01 9 7940	04 4 3040	00-4 0580	02-5 2040	00 1 7780	03 2 8030	00 9 7060	04 4 1550	00
9 3300	01 9 8390	04 4 0130	00-6 4600	02-4 0970	00 1 7100	03 1 8110	00 9 7590	04 4 1210	00
1 0000	02 9 8760	04 3 5910	00-7 5370	02-3 1700	00 1 5680	03 1 0940	00 9 8060	04 3 8500	00

ASYNCHRONOUS BEARING CHARACTERISTICS

MINOR MODE									
FREQUENCY	STIFFNESS	CR DAMP	ELLIPTIC	ORIENT	STIFFNESS	CR DAMP	ELLIPTIC	ORIENT	***MAJOR MODE***
5 0000	01 9 4910	04-1 7110	02 8 8790	01 1 4280	02 9 9660	04 7 3480	03-6 9040	01 2 7860	01
5 3590	01 9 4280	04-1 5350	02 8 7660	01 1 4060	02 9 9680	04 7 1330	03-6 7970	01 2 0810	02
5 7430	01 9 3640	04-1 2380	02 8 6420	01 1 3860	02 9 9700	04 6 9140	03-6 6840	01 2 0840	02
6 1560	01 9 3080	04-7 8970	03 8 5060	01 1 3690	02 9 9710	04 6 6930	03-6 5650	01 2 0860	02
6 5980	01 9 2760	04-1 9220	03 8 3590	01 1 3550	02 9 9730	04 6 4700	03-6 4410	01 2 0890	02
7 0710	01 9 2830	04 4 8640	03 8 2020	01 1 3420	02 9 9750	04 6 2440	03-6 3110	01 2 0910	02
7 3790	01 9 3340	04 1 1200	02 8 0350	01 1 3310	02 9 9770	04 6 0180	03-6 1750	01 2 0940	02
8 1230	01 9 4200	04 1 5880	02 7 8590	01 1 3210	02 9 9790	04 5 7920	03-6 0340	01 2 0960	02
8 7060	01 9 5200	04 1 8470	02 7 6740	01 1 3120	02 9 9800	04 5 5650	03-5 8870	01 2 0990	02
9 3300	01 9 6160	04 1 9250	02 7 4810	01 1 3040	02 9 9820	04 5 3400	03-5 7350	01 2 1010	02
1 0000	02 9 6990	04 1 8830	02 7 2810	01 1 2970	02 9 9830	04 5 1160	03-5 5780	01 2 1030	02

SAMPLE 6

DATA LINES IN RSVF FORMAT

9.8260	04-3	2740	00	2	7490	03-2	9280	00-2	1340	03	5	1280	00	9.9210	04-5	4130	00		
9.8490	04-3	2690	00	2	7620	03-2	9710	00-2	1360	03	5	2310	00	9.9190	04-5	4200	00		
9.8710	04-3	2610	00	2	7790	03-3	0310	00-2	1390	03	5	2890	00	9.9160	04-5	4300	00		
9.8680	04-3	2490	00	2	8030	03-3	1150	00-2	1420	03	5	3720	00	9.9120	04-5	4410	00		
9.8630	04-3	2300	00	2	8350	03-3	2350	00-2	1460	03	5	4870	00	9.9060	04-5	4540	00		
9.8560	04-3	1970	00	2	8790	03-3	4080	00-2	1480	03	5	6490	00	9.8980	04-5	4660	00		
9.8460	04-3	1390	00	2	9380	03-3	6580	00-2	1460	03	5	8790	00	9.8860	04-5	4690	00		
9.8310	04-3	0310	00	3	0130	03-4	0290	00-2	1310	03	6	2050	00	9.8690	04-5	4430	00		
9.8090	04-2	8200	00	3	1000	03-4	5860	00-2	0810	03	6	6640	00	9.8410	04-5	3390	00		
9.7750	04-2	3890	00	3	1730	03-5	4270	00-1	9450	03	7	2840	00	9.7970	04-5	0270	00		
9.7210	04-1	4850	00	3	1310	03-6	6430	00-1	5940	03	8	0030	00	9.7300	04-4	1940	00		
9.7270	04-1	4850	00	3	1310	03-6	6430	00-1	5940	03	8	0030	00	9.7300	04-4	1940	00		
9.7020	04-2	4740	01	3	0160	03-7	2590	00-1	3180	03	8	2540	00	9.6940	04-3	5280	00		
9.6790	04-1	4730	02	2	7940	03-7	8610	00-9	3440	02	8	3660	00	9.6540	04-2	5920	00		
9.6410	04-1	0320	00	2	4270	03-8	3320	00-4	3200	02	8	2190	00	9.6180	04-1	3560	00		
9.6560	04-1	1330	00	1	9000	03-8	5070	00	1	6300	02	7	6910	00	9.5940	04	1	1990-01	
9.6260	04-3	1960	00	1	2510	03-8	2350	00	7	7230	02	6	7320	00	9.5900	04	1	6470	00
9.7100	04-3	9840	00	5	8020	02-7	4850	00	1	2840	03	5	4430	00	9.6110	04	2	9470	00
9.7450	04-4	2290	00	4	2450	00-8	3970	00	1	6110	03	4	0560	00	9.6530	04	3	7980	00
9.7490	04-4	3040	00-4	0580	02-5	2040	00	1	7380	03	2	8030	00	9.7060	04	4	1550	00	
9.8350	04-4	0130	00-6	4600	02-4	0970	00	1	7100	03	1	8110	00	9.7590	04	4	1210	00	
9.3760	04-5	5910	00-7	5370	02-3	1700	00	1	5860	03	1	0940	00	9.8060	04	3	8500	00	

APPENDIX B

SHORT JOURNAL BEARING

The short bearing analysis of Dubois and Ccvmk [10] makes available explicit analytical expressions for the dynamic perturbation coefficients of circular and journal bearings valid for $L/D \leq 0.25$. Although these results are not precise enough for direct use at larger values of L/D , they still yield valid qualitative trends between the dynamic perturbation coefficients and static operating condition. The essential elements of this important work are summarized here.

Under the assumptions of an isoviscous lubricant and negligible misalignment, the governing equation for the film pressure of a short circular arc bearing is reduced to

$$\frac{\partial p}{\partial z^2} = \frac{6\mu}{h^3} \left(\omega \frac{\partial}{\partial \theta} + 2 \frac{\partial}{\partial t} \right) h \quad (B-1)$$

The film thickness as illustrated in Fig. B-1, is given by the equation

$$h = C\{1 - \epsilon \cos(\theta - \psi)\} \quad (B-2)$$

Separating static equilibrium and dynamic perturbation parts, one can write

$$\epsilon = \epsilon_0 + \delta\epsilon; \quad \psi = \psi_0 + \delta\psi; \quad h = h_0 + \delta h$$

$$h_0 = C\{1 - \epsilon_0 \cos(\theta - \psi_0)\} \quad (B-3)$$

$$\delta h = -\delta\epsilon \cos(\theta - \psi_0) - \epsilon_0 \delta\psi \sin(\theta - \psi_0)$$

Integration of Eq. (B-1) with respect to z twice, one finds

$$p = \frac{3\mu}{h} \left(z^2 - \frac{L^2}{4} \right) \left(\omega \frac{\partial}{\partial \theta} + 2 \frac{\partial}{\partial t} \right) h \quad (B-4)$$

Integrating over the full bearing length, one obtains

$$q = \int_{-\frac{L}{2}}^{\frac{L}{2}} p dz = - \frac{\mu L^3}{2h^3} \left(\omega \frac{\partial}{\partial \theta} + 2 \frac{\partial}{\partial t} \right) h \quad (B-5)$$

Substituting Eq. (B-3) into Eq. (B-5) and separate static equilibrium and dynamic perturbation parts, one obtains

$$q = q_0 + \delta q \quad (B-6)$$

$$q_0 = - \left(\frac{\mu \omega L^3}{2C^2} \right) \frac{\epsilon_0 \sin(\theta - \psi_0)}{\{1 - \epsilon_0 \cos(\theta - \psi_0)\}^3} \quad (B-7)$$

$$\begin{aligned} \delta q = & - \left(\frac{\mu \omega L^3}{2C^2} \right) \{ (f_1 + \epsilon_0 f_3) \delta \epsilon - (f_2 - \epsilon_0 f_4) \epsilon_0 \delta \psi \} \\ & + \left(\frac{\mu L^3}{C^2} \right) (f_2 \delta \dot{\epsilon} + f_1 \epsilon_0 \delta \dot{\psi}) \end{aligned} \quad (B-8)$$

$$\begin{aligned} f_1 &= \frac{\sin(\theta - \psi_0)}{\{1 - \epsilon_0 \cos(\theta - \psi_0)\}^3} ; & f_2 &= \frac{\cos(\theta - \psi_0)}{\{1 - \epsilon_0 \cos(\theta - \psi_0)\}^3} \\ f_3 &= \frac{3 \sin(\theta - \psi_0) \cos(\theta - \psi_0)}{\{1 - \epsilon_0 \cos(\theta - \psi_0)\}^4} ; & f_4 &= \frac{3 \sin^2(\theta - \psi_0)}{\{1 - \epsilon_0 \cos(\theta - \psi_0)\}^4} \end{aligned} \quad (B-9)$$

Global effects are obtained by integrating over projected areas through appropriate limits θ_1 and θ_2 . That is

$$(F_R, F_T) = \int_{\theta_1}^{\theta_2} q_0 \{ \cos(\theta - \psi_0), -\sin(\theta - \psi_0) \} R d\theta \quad (B-10)$$

$$\begin{aligned} & \frac{\partial(F_\epsilon, F_\psi)}{\partial e} \\ &= \left(\frac{\mu \omega L^3 R}{2C^3} \right) \int_{\theta_1}^{\theta_2} (f_1 + \epsilon_o f_3) \{ \cos(\theta - \psi_o), \sin(\theta - \psi_o) \} d\theta \end{aligned} \quad (B-11)$$

$$\begin{aligned} & \frac{\partial(F_\epsilon, F_\psi)}{e_o \partial \psi} \\ &= - \left(\frac{\mu \omega L^3 R}{2C^3} \right) \int_{\theta_1}^{\theta_2} (f_2 - \epsilon_o f_4) \{ \cos(\theta - \psi_o), \sin(\theta - \psi_o) \} d\theta \end{aligned} \quad (B-12)$$

$$\begin{aligned} & \frac{\partial(F_\epsilon, F_\psi)}{\partial e} \\ &= - \left(\frac{\mu L^3 R}{C^3} \right) \int_{\theta_1}^{\theta_2} f_2 \{ \cos(\theta - \psi_o), \sin(\theta - \psi_o) \} d\theta \end{aligned} \quad (B-13)$$

$$\begin{aligned} & \frac{\partial(F_\epsilon, F_\psi)}{e_o \partial \psi} \\ &= - \left(\frac{\mu L^3 R}{C^3} \right) \int_{\theta_1}^{\theta_2} f_1 \{ \cos(\theta - \psi_o), \sin(\theta - \psi_o) \} d\theta \end{aligned} \quad (B-14)$$

Closed form integrals are available:

$$\begin{aligned} & \int \frac{\sin(\theta - \psi_o) \cos(\theta - \psi_o) d\theta}{\{1 - \epsilon_o \cos(\theta - \psi_o)\}^3} \\ &= \frac{1 - 2\epsilon_o \cos(\theta - \psi_o)}{2\epsilon_o^2 \{1 - \epsilon_o \cos(\theta - \psi_o)\}^2} \end{aligned} \quad (B-15)$$

$$\int \frac{\sin^2(\theta - \psi_0) d\theta}{\{1 - \epsilon_0 \cos(\theta - \psi_0)\}^3}$$

$$= \frac{\chi - \sin\chi \cos\chi}{2(1 - \epsilon_0^2)^{3/2}} \quad (\text{B-16})$$

where

$$\chi = 2 \tan^{-1} \left[\sqrt{\frac{1 + \epsilon_0}{1 - \epsilon_0}} \tan \left(\frac{\theta - \psi_0}{2} \right) \right] \quad (\text{B-17})$$

$$\int f_1 \cos(\theta - \psi_0) d\theta = \int f_2 \sin(\theta - \psi_0) d\theta$$

$$= -\frac{1}{2} \left[\frac{\cos(\theta - \psi_0)}{1 - \epsilon_0 \cos(\theta - \psi_0)} \right]^2 \quad (\text{B-18})$$

$$\int f_2 \cos(\theta - \psi_0) d\theta$$

$$= (1 - \epsilon_0^2)^{-5/2} \left\{ \left(\frac{1}{2} + \epsilon_0^2 \right), \chi + \sin\chi \left(2\epsilon_0 + \frac{1}{2} \cos\chi \right) \right\} \quad (\text{B-19})$$

$$\int f_1 \sin(\theta - \psi_0) d\theta$$

$$= \frac{1}{2} (1 - \epsilon_0^2)^{-3/2} \{ \chi - \sin\chi \cos\chi \} \quad (\text{B-20})$$

$$\int f_3 \cos(\theta - \psi_0) d\theta = - \left[\frac{\cos(\theta - \psi_0)}{1 - \epsilon_0 \cos(\theta - \psi_0)} \right]^3 \quad (\text{B-21})$$

$$\begin{aligned}
\int f_4 \cos (\theta - \psi_o) d\theta &= \int f_3 \sin (\theta - \psi_o) d\theta \\
&= (1 - \epsilon_o^2)^{-5/2} \left\{ \frac{3}{2} \epsilon_o (\chi - \sin \chi \cos \chi) + \sin^3 \chi \right\}
\end{aligned} \tag{B-22}$$

$$\int f_4 \sin (\theta - \psi_o) d\theta = \frac{\cos^3 (\theta - \psi_o) - \frac{1}{\epsilon_o}}{\{1 - \epsilon_o \cos (\theta - \psi_o)\}^3} \tag{B-23}$$

Consider now the full cylindrical journal bearing. Accepting the Gumbel cavitation condition and the assumption of film initiation at the maximum gap, then for the static equilibrium problem,

$$\theta_1 = -\pi + \psi_o; \quad \theta_2 = \psi_o \tag{B-24}$$

Consequently,

$$F_R = \left(\frac{\mu \omega L^3 R}{C^2} \right) \frac{\epsilon_o^2}{(1 - \epsilon_o^2)^2}; \quad F_T = \left(\frac{\mu \omega L^3 R}{C^2} \right) \frac{\pi \epsilon_o}{4(1 - \epsilon_o^2)^{3/2}}$$

or

$$\bar{W} = \left(\frac{\pi L}{D} \right)^2 \frac{\epsilon_o \sqrt{1 - \epsilon_o^2 + \left(4 \frac{\epsilon_o}{\pi} \right)^2}}{(1 - \epsilon_o^2)^2} \quad \psi_o = \tan^{-1} \left(\frac{\pi \sqrt{1 - \epsilon_o^2}}{4 \epsilon_o} \right) \tag{B-25}$$

represent the dimensionless static equilibrium operating parameters previously defined in Section 2.

Note that

$$\lim_{\epsilon_o \rightarrow 0} \bar{W} = \left(\pi \frac{L}{D}\right)^2 \epsilon_o$$

$$\lim_{\epsilon_o \rightarrow 1} \bar{W} = \left(\frac{L}{D}\right)^2 \frac{4\pi}{(1-\epsilon_o)^2}$$

Thus

$$\lim_{\bar{W} \rightarrow 0} \epsilon_o = \left(\pi \frac{L}{D}\right)^{-2} \bar{W}$$

$$\lim_{\bar{W} \rightarrow \infty} 1-\epsilon_o = 2\left(\frac{L}{D}\right) \sqrt{\frac{\pi}{\bar{W}}}$$

respectively depict near-field and far-field asymptotic behaviors.

For the perturbation problems, θ_1 would remain unchanged but θ_2 would be shifted so the sum $q_o + \delta q$ vanishes. Therefore,

$$\theta_2 = \theta_{20} + \delta\theta_2$$

$$\left(\frac{\partial q_o}{\partial \theta}\right)_{\theta_{20}} \delta\theta_2 + (\delta q)_{\theta_{20}} = 0$$

$$\delta\theta_2 = - \left(\frac{\delta q}{\partial q_o / \partial \theta}\right)_{\theta_{20}} \quad (B-26)$$

From Eqs. (B-8 and B-9), since at $\theta = \theta_{20} = \psi_o$

$$(f_1, f_3, f_4)_{\theta_{20}} = 0$$

$$f_2 = (1-\epsilon_o)^{-3} \quad (B-27)$$

$\delta\theta_2$ is zero for perturbations with respect to $\delta\epsilon$ and $\delta\psi$ and needs to be evaluated only for perturbations with respect to $\delta\psi$ and $\delta\epsilon$. Differentiating Eq. (B-7) with respect to θ , one finds

$$\frac{\partial q_0}{\partial \theta} = - \left(\frac{\mu \omega L^3}{2C^2} \right) \frac{\epsilon_0}{\{1 - \epsilon_0 \cos(\theta - \psi_0)\}^3} \left[\cos(\theta - \psi_0) - \frac{3\epsilon_0 \sin(\theta - \psi_0)}{\{1 - \epsilon_0 \cos(\theta - \psi_0)\}} \right]$$

Therefore,

$$\delta\theta_2 = \delta\psi + \frac{2}{\epsilon_0} \delta\epsilon \quad (B-28)$$

Accordingly, allowing for the perturbed shift of θ_2 , from Eq. (B-10), one finds

$$(F_R, F_T) = - \left(\frac{\mu \omega L^3 R}{2C^2} \right) \left(-\frac{\delta\theta_2^2}{2} \right), - \left(\frac{\delta\theta_2^3}{3} \right) \frac{\epsilon_0}{(1 - \epsilon_0)^3} \quad (B-29)$$

Clearly, in comparison with terms given by Eqs. (B-11) through (B-14), these are higher order effects and can be omitted from a dynamic perturbation analysis.

Upon substituting Eq. (B-24) for the limits of integration of Eqs. (B-18) through (B-23), Eqs. B-11) through (B-14) become

$$\frac{C^2}{\mu \omega L^3 R} \begin{bmatrix} \delta F_\epsilon \\ \delta F_\psi \end{bmatrix} = - \begin{bmatrix} \bar{Z}_{\epsilon\psi} \end{bmatrix} \begin{bmatrix} \delta \epsilon \\ \epsilon_0 \delta \psi \end{bmatrix}$$

$$= - \begin{bmatrix} \frac{2\epsilon_0(1+\epsilon_0^2)}{(1-\epsilon_0^2)^3} + \frac{\pi(1+2\epsilon_0^2)}{2(1-\epsilon_0^2)^{5/2}} \frac{d}{\omega dt} & \frac{\pi}{4(1-\epsilon_0^2)^{3/2}} - \frac{2\epsilon_0}{(1-\epsilon_0^2)^2} \frac{d}{\omega dt} \\ \frac{-\pi(1+2\epsilon_0^2)}{4(1-\epsilon_0^2)^{5/2}} - \frac{2\epsilon_0}{(1-\epsilon_0^2)^2} \frac{d}{\omega dt} & \frac{\epsilon_0}{(1-\epsilon_0^2)^2} + \frac{\pi}{2(1-\epsilon_0^2)^{3/2}} \frac{d}{\omega dt} \end{bmatrix} \begin{bmatrix} \delta \epsilon \\ \epsilon_0 \delta \psi \end{bmatrix}$$

(B-30)

Using the nomenclature and coordinate system defined in Section 2, one obtains

$$\left\{ 4\pi \left(\frac{L}{D} \right)^2 \right\}^{-1} \left\{ \bar{K} \right\}_{\text{short bearing}}$$

$$= \begin{bmatrix} \cos \psi_0 & \sin \psi_0 \\ \sin \psi_0 & \cos \psi_0 \end{bmatrix} \begin{bmatrix} \frac{2\epsilon_0(1+\epsilon_0^2)}{(1-\epsilon_0^2)^3} & \frac{\pi}{4(1-\epsilon_0^2)^{3/2}} \\ \frac{\pi(1+2\epsilon_0^2)}{4(1-\epsilon_0^2)^{5/2}} & \frac{\epsilon_0}{(1-\epsilon_0^2)^2} \end{bmatrix} \begin{bmatrix} \cos \psi_c & \sin \psi_c \\ -\sin \psi_c & \cos \psi_c \end{bmatrix}$$

(B-31)

$$\{4\pi \left(\frac{L}{D}\right)^{2-1} \omega \left[\bar{B}\right]$$

$$= \begin{Bmatrix} \cos\psi_0 & -\sin\psi_0 \\ \sin\psi_0 & \cos\psi_0 \end{Bmatrix} \begin{Bmatrix} \frac{\pi(1+2\epsilon_0^2)}{2(1-\epsilon_0^2)^{5/2}} & \frac{-2\epsilon_0}{(1-\epsilon_0^2)^2} \\ \frac{-2\epsilon_0}{(1-\epsilon_0^2)^2} & \frac{\pi}{2(1-\epsilon_0^2)^{3/2}} \end{Bmatrix} \begin{Bmatrix} \cos\psi_0 & \sin\psi_0 \\ -\sin\psi_0 & \cos\psi_0 \end{Bmatrix}$$

(B-32)

Numerical results for Eqs. (B-25), (B-) and (B-32) are given in Table B-1. These results can be used to illustrate the natural motion analysis discussed in Section 2.4. At each static equilibrium condition as may be fixed by ϵ_0 of \bar{W} , the set of eight (dimensionless) dynamic perturbation coefficients can be used to calculate the stiffness and damping constants $(\bar{k}_0, (\nu/\omega) \bar{b}_0)$ as functions of the frequency ratio (ν/ω) . At each (ν/ω) there are two sets of $(\bar{k}_0, (\nu/\omega) \bar{b}_0)$ corresponding to the alternate signs in Eq. (20). One can define

$$\bar{m}_0 = \bar{k}_0 (\nu/\omega)^{-2}$$

which may be called the consistent (dimensionless) mass of the natural motion. Accordingly, one can further define the consistent dimensionless gravitational acceleration as

$$\bar{g}_0 = \bar{W}/\bar{m}_0 = (\nu/\omega)^2 \bar{W}/\bar{k}_0$$

TABLE B-1

STATIC AND DYNAMIC CHARACTERISTICS OF SHORT JOURNAL BEARING

ecc	load	att angle	K-xx	B-xx	K-xy	B-xy	K-yx	B-yx	K-yy	B-yy
0.0000	0.0000E+00	90.0000	0.0000E+00	1.5707E+00	7.8539E-01	0.0000E+00	-7.8539E-01	0.0000E+00	0.0000E+00	1.5707E+00
0.0250	1.9663E-02	88.1762	5.103E-02	1.5754E+00	7.8840E-01	5.0054E-02	-7.8533E-01	5.0054E-02	5.0052E-02	1.5720E+00
0.0500	3.9437E-02	86.3528	5.0832E-02	1.5895E+00	7.9747E-01	1.0044E-01	-7.8515E-01	1.0044E-01	1.0042E-01	1.5757E+00
0.0750	5.9677E-02	84.5238	7.7831E-02	1.6131E+00	8.1275E-01	1.5143E-01	-7.8483E-01	1.5143E-01	1.5143E-01	1.5819E+00
0.1000	8.0382E-02	82.7077	1.0678E-01	1.6468E+00	8.3446E-01	2.0356E-01	-7.8435E-01	2.0356E-01	2.0343E-01	1.5908E+00
0.1250	1.0180E-01	80.8856	1.3843E-01	1.6909E+00	8.6296E-01	2.5703E-01	-7.8367E-01	2.5703E-01	2.5675E-01	1.6023E+00
0.1500	1.2415E-01	79.0667	1.7360E-01	1.7463E+00	8.9869E-01	3.1228E-01	-7.8276E-01	3.1228E-01	3.1180E-01	1.6166E+00
0.1750	1.4765E-01	77.2482	2.1324E-01	1.8137E+00	9.4226E-01	3.6975E-01	-7.8155E-01	3.6975E-01	3.6898E-01	1.6338E+00
0.2000	1.7254E-01	75.4312	2.5844E-01	1.8945E+00	9.9440E-01	4.2932E-01	-7.7995E-01	4.2932E-01	4.2876E-01	1.6541E+00
0.2250	1.9912E-01	73.6157	3.1049E-01	1.9899E+00	1.0560E+00	4.9333E-01	-7.7789E-01	4.9333E-01	4.9166E-01	1.6773E+00
0.2500	2.2763E-01	71.8017	3.7092E-01	2.1017E+00	1.1282E+00	5.6059E-01	-7.7521E-01	5.6059E-01	5.5825E-01	1.7052E+00
0.2750	2.5833E-01	69.9822	4.4153E-01	2.2321E+00	1.2125E+00	6.3241E-01	-7.7177E-01	6.3241E-01	6.2923E-01	1.7365E+00
0.3000	2.9237E-01	68.1780	5.2477E-01	2.3837E+00	1.3105E+00	7.0958E-01	-7.6736E-01	7.0958E-01	7.0537E-01	1.7721E+00
0.3250	3.2940E-01	66.3679	6.2324E-01	2.5596E+00	1.4243E+00	7.9308E-01	-7.6172E-01	7.9308E-01	7.8757E-01	1.8125E+00
0.3500	3.7032E-01	64.5584	7.4050E-01	2.7633E+00	1.5565E+00	8.8401E-01	-7.5452E-01	8.8401E-01	8.7694E-01	1.8583E+00
0.3750	4.1583E-01	62.7492	8.8091E-01	3.0014E+00	1.7103E+00	9.8371E-01	-7.4534E-01	9.8371E-01	9.7474E-01	1.9093E+00
0.4000	4.6633E-01	60.9396	1.0500E+00	3.2781E+00	1.8896E+00	1.0338E+00	-7.3362E-01	1.0338E+00	1.0825E+00	1.9683E+00
0.4250	5.2432E-01	59.1289	1.2550E+00	3.6017E+00	2.0994E+00	1.2162E+00	-7.1867E-01	1.2162E+00	1.2022E+00	2.0345E+00
0.4500	5.8961E-01	57.3161	1.5052E+00	3.9818E+00	2.3460E+00	1.3534E+00	-6.9956E-01	1.3534E+00	1.3360E+00	2.1045E+00
0.4750	6.6423E-01	55.5003	1.8125E+00	4.4305E+00	2.6374E+00	1.5082E+00	-6.7507E-01	1.5082E+00	1.4868E+00	2.1945E+00
0.5000	7.5033E-01	53.6802	2.1935E+00	4.9635E+00	2.9839E+00	1.6845E+00	-6.4360E-01	1.6845E+00	1.6582E+00	2.2916E+00
0.5250	8.5042E-01	51.8541	2.6696E+00	5.6015E+00	3.3990E+00	1.8869E+00	-6.0298E-01	1.8869E+00	1.8548E+00	2.4025E+00
0.5500	9.6772E-01	50.0203	3.2704E+00	6.3712E+00	3.9004E+00	2.1215E+00	-5.5027E-01	2.1215E+00	2.0822E+00	2.5301E+00
0.5750	1.1065E+00	48.1766	4.0373E+00	7.3089E+00	4.5118E+00	2.3960E+00	-4.8142E-01	2.3960E+00	2.3479E+00	2.6776E+00
0.6000	1.2723E+00	46.3207	5.0284E+00	8.4638E+00	5.2657E+00	2.7208E+00	-3.9078E-01	2.7208E+00	2.6619E+00	2.8492E+00
0.6250	1.4735E+00	44.4493	6.3273E+00	9.9038E+00	6.2069E+00	3.1038E+00	-2.7030E-01	3.1038E+00	3.0375E+00	3.0505E+00
0.6500	1.7192E+00	42.5591	8.0576E+00	1.1725E+01	7.3988E+00	3.5819E+00	-1.0830E-01	3.5819E+00	3.4928E+00	3.2830E+00
0.6750	2.0263E+00	40.6457	1.0405E+01	1.4067E+01	8.9333E+00	4.1635E+00	1.1253E-01	4.1635E+00	4.0530E+00	3.5743E+00
0.7000	2.4140E+00	38.7040	1.3682E+01	1.7136E+01	1.0947E+01	4.8926E+00	4.1861E-01	4.8926E+00	4.7545E+00	3.9203E+00
0.7250	2.9143E+00	36.7276	1.8294E+01	2.1250E+01	1.3649E+01	5.8249E+00	8.5136E-01	5.8249E+00	5.6505E+00	4.3461E+00
0.7500	3.5748E+00	34.7085	2.5084E+01	2.6913E+01	1.7374E+01	7.0452E+00	1.4781E+00	7.0452E+00	6.8221E+00	4.8793E+00
0.7750	4.4717E+00	32.6371	3.5408E+01	3.4962E+01	2.2677E+01	8.6879E+00	2.4136E+00	8.6879E+00	8.3976E+00	5.5641E+00
0.8000	5.7313E+00	30.5001	5.1824E+01	4.6864E+01	3.0527E+01	1.0975E+01	3.8623E+00	1.0975E+01	1.0583E+01	6.4653E+00
0.8250	7.5771E+00	28.2804	7.9435E+01	6.5552E+01	4.2738E+01	1.4301E+01	6.2150E+00	1.4301E+01	1.3773E+01	7.6943E+00
0.8500	1.0434E+01	25.9543	1.2941E+02	9.5074E+01	6.2939E+01	1.9408E+01	1.0279E+01	1.9408E+01	1.8655E+01	9.4471E+00
0.8750	1.5196E+01	23.4872	2.2920E+02	1.5125E+02	9.9592E+01	2.7852E+01	1.7920E+01	2.7852E+01	2.6724E+01	1.2103E+01
0.9000	2.4006E+01	20.8260	4.5541E+02	2.6401E+02	1.7437E+02	4.3951E+01	3.4119E+01	4.3951E+01	4.1516E+01	1.6490E+01
0.9250	4.3132E+01	17.8505	1.1117E+03	5.4159E+02	3.5857E+02	7.6740E+01	7.5439E+01	7.6740E+01	7.3353E+01	2.4758E+01
0.9500	9.8049E+01	14.4747	3.8359E+03	1.4915E+03	9.9024E+02	1.7186E+02	2.2226E+02	1.7186E+02	1.6397E+02	4.4366E+01
0.9750	3.3615E+02	10.1481	3.1348E+04	8.4334E+03	5.6112E+03	6.8404E+02	1.3332E+03	6.8404E+02	6.5139E+02	1.2243E+02

Geometrical characterization of the natural orbit can be described in terms of the ratio of the minor radius to the major radius and the orientation angle of the major axis measured from the static equilibrium load vector. Tables B-2 (a) and B-2 (b) list results of natural orbit analysis performed for the short journal bearing at two static equilibrium conditions. Mode 1 and Mode 2, respectively, correspond to the lower and upper signs of Eq. (20). Symbols used in the headings of these tables are defined as follows:

ecc	static equilibrium eccentricity, ratio, ϵ_0
freq.	v/ω
G	dimensionless consistent gravitational acceleration, $g_0/(C\omega^2)$
K	dimensionless stiffness constant, $k_0 C^3/(\mu\omega L^3 R)$
N*C	dimensionless damping constant, $\nu b_0 C^3/(\mu\omega L^3 R)$
b/a	minor/major radius ratio
orient	orientation angle in degrees of major axis measured from load vector

Table B-2 (a) is for $\epsilon_0 = 0.5$. Negative damping is indicated in the range

$$0 < \frac{v}{\omega} < 0.5$$

for Mode 1 which has a positive value of minor/major radius ratio at all frequencies, indicating a forward whirling mode. A lower bound of consistent gravitational acceleration for stable operation is

$$\left(\frac{g_0}{C\omega^2}\right)_{\text{lower bound}} \approx 0.15$$

The corresponding consistent mass is often called the critical mass for instability. Mode 2 has a positive damping at all frequencies and has a negative minor/major radius ratio, indicating a backward whirl orbit. Table B-2 (b) is for $\epsilon_0 = 0.8$. The damping constant is positive at all frequencies. Thus, by static loading, it is possible to suppress instability.

TABLE B-2

NATURAL ORBIT PARAMETERS OF SHORT JOURNAL BEARING

ecc	freq	G	K	N#C	b/a	orient	G	K	N#C	b/a	orient
0.5000	0.0000	0.0000E+00	1.9259E+00	-1.3597E+00	0.4511	-6.4410	0.0000E+00	1.9259E+00	1.3597E+00	-0.4511	-6.4410
	0.1000	4.2683E-03	1.7580E+00	-1.0240E+00	0.4805	-12.3095	3.5837E-03	2.0938E+00	1.7495E+00	-0.4204	-0.6731
	0.2000	1.8675E-02	1.6071E+00	-7.3577E-01	0.5034	-19.1600	1.3371E-02	2.2446E+00	2.1868E+00	-0.3914	4.1591
	0.3000	4.5607E-02	1.4807E+00	-4.8114E-01	0.5155	-26.3147	2.8482E-02	2.3710E+00	2.6577E+00	-0.3646	8.0507
	0.4000	8.7135E-02	1.3778E+00	-2.4863E-01	0.5157	-32.4167	4.8529E-02	2.4739E+00	3.1507E+00	-0.3397	11.1348
	0.5000	1.4489E-01	1.2947E+00	-3.0917E-02	0.5058	-37.7218	7.3361E-02	2.5571E+00	3.6585E+00	-0.3168	13.5747
	0.6000	2.2009E-01	1.2373E+00	1.7630E-01	0.4890	-42.1473	1.0292E-01	2.6244E+00	4.1768E+00	-0.2958	15.5145
	0.7000	3.1359E-01	1.1725E+00	3.7561E-01	0.4683	-45.7500	1.3723E-01	2.6793E+00	4.7030E+00	-0.2765	17.0685
	0.8000	4.2593E-01	1.1275E+00	5.6865E-01	0.4459	-48.6525	1.7627E-01	2.7243E+00	5.2355E+00	-0.2589	18.3243
	0.9000	5.5746E-01	1.0903E+00	7.5655E-01	0.4232	-50.9881	2.2009E-01	2.7615E+00	5.7731E+00	-0.2429	19.3481
	1.0000	7.0832E-01	1.0593E+00	9.4013E-01	0.4011	-52.8755	2.6871E-01	2.7924E+00	6.3150E+00	-0.2284	20.1898
	1.2000	1.0681E+00	1.0115E+00	1.2957E+00	0.3604	-55.6721	3.8043E-01	2.8402E+00	7.4095E+00	-0.2032	21.4709
	1.4000	1.5050E+00	9.7717E-01	1.6421E+00	0.3250	-57.5863	5.1162E-01	2.8746E+00	8.5151E+00	-0.1822	22.3781
	1.6000	2.0182E+00	9.5181E-01	1.9790E+00	0.2947	-58.9413	6.6239E-01	2.9000E+00	9.6293E+00	-0.1648	23.0385
	1.8000	2.6066E+00	9.3270E-01	2.3091E+00	0.2689	-59.9296	8.3285E-01	2.9191E+00	1.0750E+01	-0.1500	23.5311
	2.0000	3.2695E+00	9.1803E-01	2.6340E+00	0.2468	-60.6698	1.0230E+00	2.9338E+00	1.1876E+01	-0.1375	23.9065
	2.2000	4.0061E+00	9.0656E-01	2.9546E+00	0.2277	-61.2369	1.2331E+00	2.9452E+00	1.3006E+01	-0.1268	24.1983
	2.4000	4.8160E+00	8.9745E-01	3.2717E+00	0.2112	-61.6802	1.4629E+00	2.9544E+00	1.4140E+01	-0.1176	24.4289
	2.6000	5.6988E+00	8.9011E-01	3.5861E+00	0.1968	-62.0326	1.7127E+00	2.9617E+00	1.5277E+01	-0.1095	24.6139
	2.8000	6.6540E+00	8.8412E-01	3.8983E+00	0.1841	-62.3172	1.9823E+00	2.9677E+00	1.6416E+01	-0.1024	24.7644
	3.0000	7.6815E+00	8.7917E-01	4.2083E+00	0.1729	-62.5501	2.2718E+00	2.9726E+00	1.7557E+01	-0.0962	24.8883
	3.2000	8.7810E+00	8.7505E-01	4.5168E+00	0.1629	-62.7429	2.5812E+00	2.9767E+00	1.8693E+01	-0.0906	24.9914
	3.4000	9.9525E+00	8.7158E-01	4.8239E+00	0.1540	-62.9043	2.9106E+00	2.9802E+00	1.9643E+01	-0.0856	25.0781
	3.6000	1.1195E+01	8.6863E-01	5.1298E+00	0.1459	-63.0407	3.2598E+00	2.9832E+00	2.0588E+01	-0.0812	25.1516
	3.8000	1.2510E+01	8.6610E-01	5.4347E+00	0.1387	-63.1569	3.6290E+00	2.9857E+00	2.1344E+01	-0.0771	25.2144
	4.0000	1.3897E+01	8.6392E-01	5.7388E+00	0.1321	-63.2567	4.0182E+00	2.9879E+00	2.2281E+01	-0.0734	25.2686

(a)

ecc	freq	G	K	N#C	b/a	orient	G	K	N#C	b/a	orient
0.8000	0.0000	0.0000E+00	7.9051E+00	0.0000E+00	0.0000	-55.1978	0.0000E+00	5.4509E+01	0.0000E+00	0.0000	5.0258
	0.1000	7.2785E-03	7.8742E+00	7.2772E-02	0.0321	-55.3687	1.0508E-03	5.4540E+01	5.2601E+00	-0.0154	5.1164
	0.2000	2.9444E-02	7.7860E+00	1.6508E-01	0.0625	-55.8624	4.1968E-03	5.4628E+01	1.0500E+01	-0.0299	5.3758
	0.3000	6.7406E-02	7.6523E+00	2.9161E-01	0.0898	-56.6279	9.4193E-03	5.4761E+01	1.5707E+01	-0.0426	5.7707
	0.4000	1.2246E-01	7.4882E+00	4.5992E-01	0.1132	-57.5963	1.6695E-02	5.4926E+01	2.0871E+01	-0.0532	6.2586
	0.5000	1.9606E-01	7.3080E+00	6.7111E-01	0.1324	-58.6955	2.6001E-02	5.5106E+01	2.5993E+01	-0.0616	6.7981
	0.6000	2.8965E-01	7.1231E+00	9.2194E-01	0.1474	-59.8608	3.7316E-02	5.5291E+01	3.1075E+01	-0.0680	7.3554
	0.7000	4.0456E-01	6.9417E+00	1.2071E+00	0.1586	-61.0397	5.0625E-02	5.5472E+01	3.6123E+01	-0.0725	7.9055
	0.8000	5.4190E-01	6.7688E+00	1.5207E+00	0.1666	-62.1931	6.5918E-02	5.5645E+01	4.1142E+01	-0.0755	8.4323
	0.9000	7.0259E-01	6.6074E+00	1.8570E+00	0.1717	-63.2946	8.3185E-02	5.5806E+01	4.6139E+01	-0.0773	8.9262
	1.0000	8.8735E-01	6.4588E+00	2.2110E+00	0.1746	-64.3279	1.0242E-01	5.5955E+01	5.1118E+01	-0.0782	9.3826
	1.2000	1.3310E+00	6.2003E+00	2.9566E+00	0.1754	-66.1620	1.4681E-01	5.6213E+01	6.1038E+01	-0.0778	10.1795
	1.4000	1.8756E+00	5.9892E+00	3.7330E+00	0.1718	-67.6862	1.9908E-01	5.6425E+01	7.0928E+01	-0.0757	10.8322
	1.6000	2.5217E+00	5.8181E+00	4.5251E+00	0.1658	-68.9331	2.5924E-01	5.6596E+01	8.0803E+01	-0.0727	11.3620
	1.8000	3.2695E+00	5.6795E+00	5.3236E+00	0.1586	-69.9479	3.2730E-01	5.6734E+01	9.0659E+01	-0.0693	11.7915
	2.0000	4.1181E+00	5.5668E+00	6.1236E+00	0.1511	-70.7744	4.0327E-01	5.6847E+01	1.0053E+02	-0.0659	12.1409
	2.2000	5.0649E+00	5.4745E+00	6.9221E+00	0.1435	-71.4505	4.8717E-01	5.6939E+01	1.1040E+02	-0.0625	12.4268
	2.4000	6.1150E+00	5.3985E+00	7.7176E+00	0.1363	-72.0068	5.7900E-01	5.7015E+01	1.2027E+02	-0.0593	12.6623
	2.6000	7.2615E+00	5.3354E+00	8.5095E+00	0.1294	-72.4679	6.7877E-01	5.7078E+01	1.3014E+02	-0.0563	12.8577
	2.8000	8.5058E+00	5.2827E+00	9.2974E+00	0.1230	-72.8530	7.8649E-01	5.7131E+01	1.4002E+02	-0.0534	13.0212
	3.0000	9.8472E+00	5.2382E+00	1.0081E+01	0.1170	-73.1769	9.0215E-01	5.7176E+01	1.4990E+02	-0.0508	13.1589
	3.2000	1.1285E+01	5.2004E+00	1.0861E+01	0.1114	-73.4513	1.0257E+00	5.7213E+01	1.5979E+02	-0.0484	13.2758
	3.4000	1.2819E+01	5.1681E+00	1.1638E+01	0.1063	-73.6855	1.1573E+00	5.7246E+01	1.6968E+02	-0.0461	13.3756
	3.6000	1.4444E+01	5.1403E+00	1.2412E+01	0.1016	-73.8866	1.2968E+00	5.7273E+01	1.7957E+02	-0.0441	13.4615
	3.8000	1.6175E+01	5.1163E+00	1.3183E+01	0.0972	-74.0604	1.4443E+00	5.7297E+01	1.8946E+02	-0.0421	13.5358
	4.0000	1.7956E+01	5.0954E+00	1.3951E+01	0.0931	-74.2115	1.5998E+00	5.7318E+01	1.9936E+02	-0.0404	13.6005

(b)

APPENDIX C

THE HALF SOMMERFELD SOLUTION

The classical solution for an infinitely long journal bearing is remembered by the name of the noted mathematician Sommerfeld [11]. The differential equation to be solved is

$$\frac{d}{d\theta} \left[\frac{h^3}{12\mu} \frac{dp}{Rd\theta} - \left(\frac{\omega R}{2} \right) h \right] = 0 \quad (C-1)$$

where $h = C (1 - \epsilon \cos\theta) = CH$. Upon integrating once,

$$\frac{dp}{d\theta} = \frac{6\mu\omega R^2}{C^2} \left(\frac{1}{H^2} - \frac{H^*}{H^3} \right) \quad (C-2)$$

H^* is the value of the dimensionless gap at the pressure peak. Integrating again

$$\begin{aligned} p &= \frac{6\mu\omega R^2}{C^2} \left\{ \left(\int \frac{d\theta}{H^2} + H^* \int \frac{d\theta}{H^3} \right) + A \right\} \\ &= \frac{6\mu\omega R^2}{C^2} \left\{ (1 - \epsilon^2)^{-3/2} (\chi + \epsilon \sin\chi) \right. \\ &\quad \left. + H^* (1 - \epsilon^2)^{-5/2} \left[\left(1 + \frac{\epsilon^2}{2} \right) \chi + 2\epsilon \sin\chi + \frac{\epsilon^2}{4} \sin 2\chi \right] + A \right\} \end{aligned}$$

where $\chi = 2 \tan^{-1} \sqrt{\frac{1+\epsilon}{1-\epsilon}} \left(\tan \frac{\theta}{2} \right)$; A is a second integration constant. Requiring p to be periodic, one finds

$$H^* = \frac{2(1 - \epsilon^2)}{2 + \epsilon^2} \quad (C-3)$$

A is set to zero since it only represents a pressure level. Thus

$$\begin{aligned}
& \frac{2\pi p C^2}{\mu \omega R^2} \\
&= \frac{-12\pi \sin \chi (2 - \epsilon^2 + \epsilon \cos \chi)}{(1 - \epsilon^2)^{3/2} (2 + \epsilon^2)} \\
&= - \frac{12\pi \epsilon (1 + H) \sin \theta}{(2 + \epsilon^2) H^2} \quad (C-4)
\end{aligned}$$

This is seen to be an odd function of θ , being positive in the converging gap but negative in the divergent gap. Gümbel [8] suggested that the lubricant film would not sustain the negative pressure so that Eq. (C-4) is valid only in the convergent half of the circumference. This is known as the half Sommerfeld solution.

Dimensionless force components based on half Sommerfeld solution are

$$\begin{aligned}
\bar{W}_R &= \frac{\pi C^2}{\mu \omega R^2} \int_{-\pi}^0 p \cos \theta \, d\theta \\
&= \frac{\pi C^2}{\mu \omega R^2} \left\{ p \sin \theta \Big|_{-\pi}^0 - \int_{-\pi}^0 \sin \theta \frac{dp}{d\theta} \, d\theta \right\} \\
&= -6\pi \int_{-\pi}^0 \left(\frac{1}{H^2} - \frac{H^*}{H^3} \right) \sin \theta \, d\theta \\
&= \frac{12\pi \epsilon^2}{(1 - \epsilon^2)(2 + \epsilon^2)} \quad (C-5)
\end{aligned}$$

$$\bar{W}_T = \frac{\pi C^2}{\mu \omega R^2} \int_{-\pi}^0 -p \sin \theta \, d\theta$$

$$= -6\pi \int_{-\pi}^0 \left(\frac{1}{H^2} - \frac{H^*}{H^3} \right) \cos \theta \, d\theta$$

$$= \frac{6\pi^2 \epsilon}{\sqrt{1-\epsilon^2} (2+\epsilon^2)} \quad (C-6)$$

Or, the dimensionless load and the attitude angle are

$$\bar{W} = \frac{2\pi W C^2}{\mu \omega R^2 L D}$$

$$= \sqrt{\bar{W}_R^2 + \bar{W}_T^2}$$

$$= \frac{6\pi^2 \epsilon}{(1-\epsilon^2)(2+\epsilon^2)} \sqrt{1 - \left(1 - \frac{4}{\pi^2}\right) \epsilon^2} \quad (C-7)$$

$$= \tan^{-1} \left(\frac{\pi \sqrt{1-\epsilon^2}}{2\epsilon} \right)$$

APPENDIX D
LISTING OF RETRIEVAL FILES

FILE NO. PJ-05-1

```

FILE SIZE = 17
L/D      = 0.5000
RLFR     = 1.1250
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8 74890-01 9.01230-01 9.32330-01 9.41600-01 9 58310-01 9 63820-01 9 77370-01
9 81300-01 9 85510-01 1 00000 00
1 00000 00 0 00000-01 4 65530-01 9 91330-01 1 00000 00-1 50710 00 0 00000-01
3 58860 01 7 99170-01-1 12750 00 5 22010 00-2 95270 01 6 76450-01-6 82180-01
9 76970-01 6 04020 00 5 91280-01-4 78620-01 1 84760 00 8 74040-01 5 45560-01
-2 35770-01 1.95910 00 1.22260 01 5 38270-01 1 78750-01 2 73820 00 2 38340 01
5.64440-01 5 32150-01 5.55160 00 6.74190 01 6 46160-01 1 37280 00 1 17800 01
1 55600 02 6 85840-01 1.69720 00 1 58800 01 2 46090 02 7 47520-01 2 31000 00
2 35320 01 4 19340 02 7 70010-01 2 54620 00 2 74120 01 7 09800 02 8 20060-01
3 14290 00 3.99820 01 5.97390 02 8 34650-01 3 32930 00 4 26760 01 1 80710 03
8 84430-01 4.07350 00 6 71620 01 5 14910 03 9 07640-01 4 43040 00 4 04770 01
1.26940 04 9.20340-01 4 84020 00 1 36350 02-9 41180 03 1 00000 00
0 00000-01-5 00000-01 9.00000 01 1 88700 02 1 00000 00-1 53910 00 0 00000-01
3 71560 01 7.95170-01-1.14600 00 5 40500 00-2 96650 01 6 71620-01-6 75590-01
1 14200 00 1 43990 00 5.86830-01-4 96030-01 1 34950 00-2 57290 00 5 33630-01
-3 44790-01 1.02130 00 6.04730 00 4 97380-01-1 32150-01 1 90120 00 1 17340 01
4 93690-01 4.84550-02 2 79400 00 7.61730 01 5.19910-01 6 29690-01 9 83160 00
1 93670 02 5 40510-01 9 55950-01 1 49340 01 6 93730 02 5 80930-01 1 75580 00
3 65070 01 7 42810 02 5 98880-01 2 12620 00 4 33950 01 3 20070 03 6 46300-01
3 39670 00 1 00090 02 1 45500 03 6 62660-01 3 86280 00 1 04640 02 1 47490 04
7 30910-01 6.66170 00 3.06490 02 3.58290 04 7.64770-01 8 41680 00 4 68720 02
6 33200 04 7 98740-01 1.05240 01 6 97540 02-4 81490 04 1 00000 00
0 00000-01 5 00000-01 1 95760 01 6 71580 00 1.00000 00 1 07000 00 0 00000-01
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-2 47280 02 1 43310 00-1.98870 00-2 67630 01-4 73870 02 1 35600 00-7 05020 00
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1 89830 01 9.41910-01-2 65460-01 2 76140 00-1 74330 01 9 23650-01-4 86570-02
2 58080-01 7 73250-01 9 19680-01-7 70950-03 3 67540-01-2 38150 00 9 21380-01
2 38000-02 6 36870-02 1.94570 00 4 26510-01 5 36480-02 3 46820-01-2 63980 00
9 31410-01 7 24150-02 1 45980-01 1 65660 01 9 40900-01 1 56690-01 1 67830 00
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-3.92310	00-7	62700	01-1	69100	04	1	32380	00-4	33900	00-1	52570	02-9	14440	03			
1.24720	00-7	24530	00-2	76460	02-7	13120	00	1	21150	00-8	57030	00-3	68750	02			
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-2.31490	02	1.55790	00-1	45840	00-3	06840	01-1	30560	03	1	49120	00-3	04100	00			
-7.12820	01	9.07220	02	1.46000	00-3	66580	00-6	28700	01-3	30020	03	1	38220	00			
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7 22130-01 7 61240 00 2 14730 02 3 99130 04 8 37440-01 1 29040 01 6 84500 02
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[illegible]

APPENDIX E

LISTING OF SOURCE PROGRAM

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C      NEW PPS DATA
C      SYSDON NAME=1      DIMENSION: KEYS FOR AFFILIATE (PTN)      1 AUGUST, 1977
      GO187
      IMPLICIT REAL*8 (A-H,O-Z)
      INTEGER*2 FN3(16),FN2(16),FN1(16)
      LOGICAL RMS
      DIMENSION X(40),Y(40),Z(40),V(40),W(40),U(40),S(40),R(40),Q(40),P(40),O(40),N(40),M(40),L(40),K(40),J(40),I(40),H(40),G(40),F(40),E(40),D(40),C(40),B(40),A(40)
      DIMENSION ZD(40),XZ(40),YZ(40),VZ(40),WZ(40),UZ(40),SZ(40),RZ(40),QZ(40),PZ(40),OZ(40),NZ(40),MZ(40),LZ(40),KZ(40),JZ(40),IZ(40),HZ(40),GZ(40),FZ(40),EZ(40),DZ(40),CZ(40),BZ(40),AZ(40)
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      RM1023=1023
      RM1024=1024
      RM1025=1025
      RM1026=1026
      RM1027=1027
      RM1028=1028
      RM1029=1029
      RM1030=1030
      RM1031=1031
      RM1032=1032
      RM1033=1033
      RM1034=1034
      RM1035=1035
      RM1036=1036
      RM1037=1037
      RM1038=1038
      RM1039=1039
      RM1040=1040
      RM1041=1041
      RM1042=1042
      RM1043=1043
      RM1044=1044
      RM1045=1045
      RM1046=1046
      RM1047=1047
      RM1048=1048
      RM1049=1049
      RM1050=1050
      RM1051=1051
      RM1052=1052
      RM1053=1053
      RM1054=1054
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      RM1056=1056
      RM1057=1057
      RM1058=1058
      RM1059=1059
      RM1060=1060
      RM1061=1061
      RM1062=1062
      RM1063=1063
      RM1064=1064
      RM1065=1065
      RM1066=1066
      RM1067=1067
      RM1068=1068
      RM1069=1069
      RM1070=1070
      RM1071=1071
      RM1072=1072
      RM1073=1073
      RM1074=1074
      RM1075=1075
      RM1076=1076
      RM1077=1077
      RM1078=1078
      RM1079=1079
      RM1080=1080
      RM1081=1081
      RM1082=1082
      RM1083=1083
      RM1084=1084
      RM1085=1085
      RM1086=1086
      RM1087=1087
      RM1088=1088
      RM1089=1089
      RM1090=1090
      RM1091=1091
      RM1092=1092
      RM1093=1093
      RM1094=1094
      RM1095=1095
      RM1096=1096
      RM1097=1097
      RM1098=1098
      RM1099=1099
      RM1100=1100
      RM1101=1101
      RM1102=1102
      RM1103=1103
      RM1104=1104
      RM1105=1105
      RM1106=1106
      RM1107=1107
      RM1108=1108
      RM1109=1109
      RM1110=1110
      RM1111=1111
      RM1112=1112
      RM1113=1113
      RM1114=1114
      RM1115=1115
      RM1116=1116
      RM1117=1117
      RM1118=1118
      RM1119=1119
      RM1120=1120
      RM1121=1121
      RM1122=1122
      RM1123=1123
      RM1124=1124
      RM1125=1125
      RM1126=1126
      RM1127=1127
      RM1128=1128
      RM1129=1129
      RM1130=1130
      RM1131=1131
      RM1132=1132
      RM1133=1133
      RM1134=1134
      RM1135=1135
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      RM1140=1140
      RM1141=1141
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      RM1156=1156
      RM1157=1157
      RM1158=1158
      RM1159=1159
      RM1160=1160
      RM1161=1161
      RM1162=1162
      RM1163=1163
      RM1164=1164
      RM1165=1165
      RM1166=1166
      RM1167=1167
      RM1168=1168
      RM1169=1169
      RM1170=1170
      RM1171=1171
      RM1172=1172
      RM1173=1173
      RM1174=1174
      RM1175=1175
      RM
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      READ (1,*) NSYN
      IF (NSYN EQ 2) GO TO 1020
      LFREQ = 1
      FRRAT = 1.0
      GO TO 1030
1020  WRITE(1,1021)
1021  FORMAT(5X,29HENTER NUMBER OF FREQ GROUPS?)
      READ (1,*) LFREQ
1030  GO TO (2100,2100,2200,102),NSEL
      GO TO 101
102  CALL EXIT
C
C    INPUT BEARING DESIGN DATA
C
2100  WRITE(1,2101)
2101  FORMAT(25HENTER BEARING LENGTH (IN))
      READ(1,*) ALEN
      WRITE(1,2102)
2102  FORMAT(27HENTER BEARING DIAMETER (IN))
      READ(1,*) ADIA
      WRITE(1,2103)
2103  FORMAT(28HENTER BEARING CLEARANCE (IN))
      READ(1,*) ACLE
      WRITE(1,2104)
2104  FORMAT(29HENTER VISCOSITY (CENTI-POISE))
      READ(1,*) ACPD
      WRITE(1,2105)
2105  FORMAT(24HENTER BEARING LOAD (LBS))
      READ(1,*) ALOA
      IF(NSEL EQ 2) GO TO 2106
      ANS=OPNF*AC(ENTER BEARING COEFS FILE NAME',29,4*WRITE*415CMF,
+FN3,LN,EW2)
      IF(ANS) GO TO 2106
      WRITE(1,2131)
2131  FORMAT(26H ERROR IN OPENING BEARING COEFS FILE)
      CALL EXIT
C
C    SPEED INDEPENDENT SCALING CONSTANTS
C
2106  COR = 2.0*ACLE/ADIA
      ALS=ALEN/ADIA
      AREA=ALEN*ADIA
      REYN=1.450377*40-07*ACPD
      ALOAD=REYN*AREA
      BHP=P4/1.1820+07*ALOAD*ADIA*ADIA/ACLE
      ALOAD=ALOAD/COR/COR
      BCPH=AREA*ACLE/2.710+02
      IF(AL8 EQ AL9) GO TO 2107
      WRITE(1,1040) AL9,ALS
1040  FORMAT(/31HSELECT: (1) USE DEFAULT L/D = P10 4/
+10X,25H(2) ADJUST DATA FOR L/D = ,F10 4-10)
      READ(1,*)NAL
      IF(NAL EQ 1) GO TO 2107
      WFAC=SHORT(AL9,AL8,ALF)

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      GO TO 2108
2107  WFAC=1.0
      AL8=AL9
2108  ALOAD=ALOAD/WFAC
      BLOAD=ALOAD/60.0
      BSTIF=BLOAD/ACLE
      BDAMP=ALOAD/ACLE/P4/8.0
      BLOA=ALOA/BLOAD
      WRITE(1,2109)
2109  FORMAT(/47HSELECT:  (1) LOAD VECTOR IN VERTICAL PLANE, OR/10X,
+25H(2) INCLINED LOAD VECTOR?)
      READ (1,*) NVEC
      IF (NVEC.EQ.1) GO TO 2135
      WRITE(1,2132)
2132  FORMAT(5X,35HENTER LOAD INCLINATION ANGLE (DEG)?)
      READ (1,*) WANG
      WRAD = WANG*P2/9.0D+01
      CC = DCOS(WRAD)
      SS = DSIN(WRAD)
      ROT(1) = CC*CC
      ROT(2) = CC*SS
      ROT(3) = SS*SS
2135  CALL BASE(NBA,BMA,BST,BDA)
C
C      SPEED LOOP FOR ARCTAN PARAMETER
C
      NMAX=11
      IF(NSEL.EQ.2) NMAX=51
2110  WRITE(1,2111)
2111  FORMAT(24HENTER LOWEST SPEED (RPM))
      READ(1,*) RPM1
      WRITE(1,2112)
2112  FORMAT(25HENTER HIGHEST SPEED (RPM))
      READ(1,*) RPM2
      WRITE(1,2113) NMAX
2113  FORMAT(43HENTER NUMBER OF SPEED POINTS (NOT MORE THAN 13,1H))
      READ(1,*) NRPM
      IF(NRPM.GT.1) GO TO 2120
      SPRAT=1.0
      GO TO 2130
2120  KP=1.0/(NRPM-1)
      SPRAT=(RPM2/RPM1)**KP
2130  RPH=RPM1
      NTHB=NRPM
      WRITE(1,2141) ALEN,ADIA,ACLE,ACPO,ALOA,RPM1,RPM2,NRPM
2141  FORMAT(2X,6HL (IN),3X,8HDIA (IN),3X,6HC (IN),3X,9HV100 (CP),2X,
+7HW (LBS),7X,17HSPEED RANGE (RPM),/2(1X,F8.4,1X),F9 6.1PD11 3,
+0PF9 2.2X,F9 2.4H TO ,F9.2,15.4H PTS/1H )
      KPAGE = KPAGE+3
      GO TO 2300
2200  WRITE(1,2201) AL9
2201  FORMAT(/14H DEFAULT L/D =.F10 4/27H ENTER DESIRED L/D OR 0 TO ,
+14HACCEPT DEFAULT)
      READ(1,*) AL8

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      IF(AL8.EQ.0) GO TO 2202
      WFAC=SHORT(AL9,AL8,ALF)
      GO TO 2203
2202  WFAC=1.0
      AL8 = AL9
2203  WRITE(1,2204)
2204  FORMAT(27HENTER LOWEST LOAD PARAMETER)
      READ(1,*) U1
      WW1=U1*WFAC
      WRITE(1,2205)
2205  FORMAT(28HENTER HIGHEST LOAD PARAMETER)
      READ(1,*) U2
      WW2=U2*WFAC
      WRITE(1,2206)
2206  FORMAT(46HENTER NUMBER OF DATA POINTS -NOT MORE THAN 51)
      READ(1,*) NTAB
      IF(NTAB.GT.1) GO TO 2207
      SPRAT = 1.0
      GO TO 2208
2207  XP = 1.0/(NTAB-1)
      SPRAT=(WW2/WW1)**XP
2208  WW=WW1
      NBR = 1
      NVEC = 1
2300  DO 2330 ITAB=1,NTAB
      IF(NSEL.EQ.3) GO TO 2310
      WW=BLOA/RPM
2310  XX(ITAB)=DATAN(WW)/P2
      WO(ITAB)=WW
      IF(NSEL.EQ.3) GO TO 2320
      XO(ITAB)=RPM
      IF (ITAB.EQ.NTAB) GO TO 2330
      RPM=RPM*SPRAT
      GO TO 2330
2320  XO(ITAB)=WW/WFAC
      IF (ITAB.EQ.NTAB) GO TO 2330
      WW=WW*SPRAT
2330  CONTINUE
C
C    RETRIEVAL LOOP
C
      WRITE(KW,2331)
2331  FORMAT(////)
      KPAGE=KPAGE+4
      IF(AL8.EQ.AL9) GO TO 2340
      WRITE(KW,2333) AL8
2333  FORMAT(37H LOAD PARAMETER IS ADJUSTED FOR L/D = .F:0.4/1H )
      KPAGE=KPAGE+2
2340  IF(NSEL.EQ.3) GO TO 2350
      WRITE(KW,2341)
2341  FORMAT(5X,3HRPM,10X,7HECC(IN),5X,9HATT ANGLE,3X,9HFRICL HP ,
+4X,10HQ-REQ(GPM),3X,11HQ-LOST(GPM))
      GO TO 2360
2350  WRITE(KW,2351)

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2351  FORMAT(5X,4HLOAD,2X,42HECC RATIO      ATT ANGLE      FRICTION      REQ.
      +19H FLOW      LOST FLOW)
2360  KPAGE=KPAGE+1
C
C      STATIC PARAMETERS
C
      DO 2390 L1=1,5
      READ(KW,2371) S1,S2,AA,BB,(C(22,I),Y1(K,1),K=1,2),L1=1 NM,C(22,MM)
2371  FORMAT(7D11.4)
C
C      ARCTAN LOOP
C
      DO 2376 ITAB=1,NTAB
      XXX=XX(ITAB)
      N1=NVHERE(XXX,X,NM)
      NPLACE(ITAB)=N1
      DX=XXX-X(N1)
      Z=SPL(ZZ,Y1,DX,N1)
      WW=W0(ITAB)
      Z1=PEFER(AA,BB,S1,S2,WW)
      Y'=Z+Z1
      IF(NSEL.EQ.3) GO TO 2375
      RPM=XG(ITAB)
      GO TO (2372,2375,2373,2374,2374),L1
2372  YY=YY*ACLE
      GO TO 2375
2373  YY=YY+BHP*RPM*RPM
      GO TO 2375
2374  YY=YY+BGPM*RPM
2375  Y0(L1,ITAB)=YY
2376  CONTINUE
2380  CCITINUE
      DO 2400 ITAB=1,NTAB
      WRITE(KW,2381) X0(ITAB),(Y0(L1,ITAB),L1=1,5)
2381  FORMAT(6(1X,1PD12.4))
      KPAGE=KPAGE+1
      IF(KPAGE.LT.61.OR.ITAB.EQ.NTAB) GO TO 2400
      KPAGE=1
      WRITE(KW,2382)
2382  FORMAT(1H1)
      IF(NSEL.EQ.3) GO TO 2390
      WRITE(KW,2341)
      GO TO 2400
2390  WRITE(KW,2351)
2400  CONTINUE
C
C      DYNAMIC PARAMETERS
C
      IF(AL8.EQ.AL9) GO TO 2420
      WRITE(KW,2412) AL8
2412  FORMAT(///48H LOAD AND DYNAMIC COEFFICIENTS ARE ADJUSTED FOR ,
      +SHL/D =,F8.4/1H )
      KPAGE = KPAGE+6
      IF (KPAGE.GT.60) KPAGE = KPAGE-60

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```

      GO TO 2415
2420  WRITE(KW,2331)
      KPAGE = KPAGE+4
      IF (KPAGE.GT.60) KPAGE = KPAGE-60
2415  IF (NSYN.EQ.2) GO TO 2445
      IF (NSEL.EQ.3) GO TO 2430
      WRITE(KW,2421)
2421  FORMAT(3X,3HRPM,7X,4HK-XX,6X,4HB-XX,6X,4HK-XY,6X,4HB-X/,6X,4HK-YY,
+6X,4HB-YY,6X,4HB-YY,6X,4HB-YY)
      GO TO 2440
2430  WRITE(KW,2431)
2431  FORMAT(2X,4HLOAD,7X,4HK-XX,6X,4HB-XX,6X,4HK-XY,6X,4HB-XY,6X,
+4HK-YY,6X,4HB-YY,6X,4HB-YY,6X,4HB-YY)
2440  KPAGE = KPAGE+1
2445  DO 2480 L1=6,13
      L=L1-5
      L2=L/2
      LL=2*L2
      READ(KT,2371) S1,S2,AA,BB,((ZZ(1+),((1+1.1+),Y=1.7+),1=1.HM+ ZZ(HH)
C
C      ARCTAN LOOP
C
      DO 2480 ITAB=1,NTAB
      XXX=XX(ITAB)
      N1=NPLACE(ITAB)
      DX=XXX-X(N1)
      Z=SPL(ZZ,Y1,DX,N1)
      WW=WO(ITAB)
      Z1=REFER(AA,BB,S1,S2,WW)
      YY=Z*Z1
      IF(NSEL.EQ.3) GO TO 2460
      IF(LL.EQ.L) GO TO 2450
      YY=YY*BSTIF*XO(ITAB)
      GO TO 2470
2450  YY=YY*BDAMP
      GO TO 2470
2460  YY=YY/WFAC
2470  YO(L,ITAB)=YY
      IF(L.NE.6) GO TO 2480
      YY=(YY+YO(4,ITAB))/2.0
      YO(L,ITAB)=YY
      YO(4,ITAB)=YY
2480  CONTINUE
      DO 2490 ITAB=1,NTAB
      IF (NSYN.EQ.1) INDX = ITAB
      DO 3000 L=1,8
      Y(L,ITAB) = YO(L,ITAB)
3000  CONTINUE
      IF (NVED.EQ.2) CALL TILT(Y,ROT,ITAB)
      DO 6030 KFF=1,LFREQ
      IF (NSYN.EQ.2) GO TO 5010
      HPRE = 1
      IF (NSEL.EQ.3) GO TO 5000
      FF = XO(ITAB)

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      GO TO 5060
5000  FF = 1.0
      GO TO 5060
5010  IF (NSEL.EQ.3) GO TO 4010
      WRITE(KW,4001) X0(ITAB)
4001  FORMAT(1H1,6H RPM = ,1PD10.3)
      GO TO 4020
4010  WRITE(KW,4002) X0(ITAB)
4002  FORMAT(1H1,7H LOAD = ,1PD10.3)
4020  WRITE(KW,5011)
5011  FORMAT(2X,4HFREQ,7X,4HK-XX,6X,4HB-XX,6X,4HK-XY,6X,4HB-XY,6X,
+4HK-YX,6X,4HB-YX,6X,4HK-YY,6X,4HB-YY)
      KPAGE=1
      IF (NSEL.EQ.3) GO TO 5015
      WRITE(1,5012) KFF,X0(ITAB)
5012  FORMAT(5X,35HENTER FREQ DATA (HZ) FOR FREQ GROUP,15,3H AT,1PD12.4,
+4H RPM/10X,12HLOWEST FREQ?)
      GO TO 5020
5015  WRITE(1,5016) KFF,X0(ITAB)
5016  FORMAT(5X,30HENTER FREQ DATA FOR FREQ GROUP,15,9H AT LOAD
+11HPARAMETER = ,1PD12.4/10X,10HLOWEST FREQ RATIO?)
5020  READ (1,*) FREQ1
      IF (NSEL.EQ.3) GO TO 5021
      FF = 6.00+01*FREQ1
      GO TO 5022
5021  FF = FREQ1
5022  IF (NSEL.NE.3) WRITE(1,5023)
5023  FORMAT(10X,13HHIGHEST FREQ?)
      IF (NSEL.EQ.3) WRITE(1,50230)
50230  FORMAT(10X,10HHIGHEST FREQ RATIO?)
      READ (1,*) FREQ2
      WRITE(1,5024)
5024  FORMAT(10X,22HNUMBER OF FREQ POINTS?)
      READ (1,*) NFRE
      IF (NSEL.EQ.3) GO TO 5040
      IF (NFRE.LE.1) GO TO 5030
      XP = 1.0/(NFRE-1)
      FFRAT = (FREQ2/FREQ1)*XP
      GO TO 5060
5030  FFRAT = 1.0
      GO TO 5060
5040  IF (NFRE.LE.1) GO TO 5050
      OFRE = (FREQ2-FREQ1)/(NFRE-1)
      GO TO 5060
5050  OFRE = 0.0
5060  DO 5200 IFRE=1,NFRE
      IF (NSYN.EQ.2) INDX = IFRE
      FREQ(INDX) = FF
      GO 5070 L=1.8
      ZEP(L,INDX) = Y(L,ITAB)
5070  CONTINUE
      IF (NBA.EQ.1 AND NSYN.EQ.2 AND IFRE.GT.1) GO TO 5103
      IF (NBA.EQ.1) GO TO 5080
      CALL GANT(FF,ZEP,INDX,NBA,BST,SDA)

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5080 IF (NSEL EQ 3) GO TO 5085
    IF (NSYN EQ 1) GO TO 5090
    GG = FF/6.00+01
    GO TO 5100
5085 IF (NSYN EQ 2) GO TO 5090
    GG = X0(ITAB)
    GO TO 5100
5090 GG = FF
5100 WRITE(LM,5101) GG,(ZEP(1),140X) L=1
    KPAGE=KPAGE+1
5101 FORMAT(1P5010.3)
    IF (NSEL EQ 1) WRITE(LM,5102) *200. INCH.
5102 FORMAT(1P5010.7)
5103 IF (NBB.NE.1 OF NSYN BE 2) GO TO 5104
    IF (IFRE EQ NFRE) GO TO 5107
    GO TO 5105
5104 IF (IFRE EQ NFRE) GO TO 5107
5105 IF (NSEL EQ 3) GO TO 5110
    FF = FF+FFREQ
    GO TO 5150
5110 FF = FF+DFRE
5150 IF (NSYN EQ 2 AND IFRE EQ NFRE) GO TO 5152
    IF (KPAGE LT.61) GO TO 5200
    WRITE(LM,2382)
    IF (NSYN EQ 1) GO TO 5152
5151 WRITE(LM,5011)
    GO TO 5190
5152 IF (NSEL EQ 3) GO TO 5153
    WRITE(LM,2421)
    GO TO 5190
5153 WRITE(LM,2421)
5190 KPAGE = 1
5200 CONTINUE
    IF (NSYN EQ 1) GO TO 6030
    IF (KPAGE LT.57) GO TO 2491
    WRITE(LM,2382)
    KPAGE = 0
    GO TO 2492
2491 WRITE(LM,2331)
    KPAGE = KPAGE+4
2492 IF (NSEL EQ 3) GO TO 2493
    FF = 6.00+01*FREQ1
    GO TO 2494
2493 FF = FREQ1
2494 WRITE(LM,6001)
6001 FORMAT(37H ASYNCHRONOUS BEARING CHARACTERISTICS:140.12X 140.14X
+10HMINOR MODE,14(1H*),2X.140.14X 140.14X 140.14X
+61H FREQUENCY STIFFNESS OR DAMP ELLIPTIC ORIENT STIFFNESS:
+28H OR DAMP ELLIPTIC ORIENT:
    KPAGE = KPAGE+3
6010 DO 6020 IFRE=1,NFRE
    FF = FREQ(IFRE)
    CALL STAB(ZEP,FF,NSEL,NSYN IFRE,FM,KPAGE)
6020 CONTINUE

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        IF (KPAGE.GE.57) GO TO 6025
        WRITE(KW,2331)
        KPAGE = KPAGE+4
        GO TO 6030
6025  WRITE(KW,2382)
        KPAGE = 0
6030  CONTINUE
        IF (NSYN.EQ.1) GO TO 2490
        IF (KPAGE.LT.61 OR.ITAB.EQ.NTAB) GO TO 2490
        WRITE (KW,2382)
        IF (NSEL.EQ.3) GO TO 6031
        WRITE (KW,2421)
        GO TO 6032
6031  WRITE(KW,2431)
6032  KPAGE = KPAGE+1
2490  CONTINUE
        IF (NSYN.EQ.2) GO TO 7000
        IF (KPAGE.LT.57) GO TO 6035
        WRITE (KW,2382)
        KPAGE = 0
        GO TO 6040
6035  WRITE (KW,2331)
        KPAGE = KPAGE+4
6040  WRITE(KW,2495)
2495  FORMAT(1X,15(1H*),25H5SYNCH BRG CHARACTERISTICS,15(1H*),2X,
+21HSTABILITY PARAMETERS)
        IF (NSEL.EQ.3) GO TO 2497
        WRITE(KW,2496)
2496  FORMAT(55H      RPM      MIN STIFF  MIN DAMP  MAX STIFF  MAX DAMP,
+22H      CR MASS      F RATIO)
        GO TO 2499
2497  WRITE(KW,2498)
2498  FORMAT(55H      LOAD      MIN STIFF  MIN DAMP  MAX STIFF  MAX DAMP,
+22H      CR MASS      F RATIO)
2499  KPAGE = KPAGE+2
        DO 2500 ITAB=1,NTAB
        FF = XO(ITAB)
        CALL STAB(ZEP,FF,NSEL,NSYN,ITAB,KW,KPAGE)
2500  CONTINUE
7000  IF(NSEL.NE.1) GO TO 2510
        WRITE(1,2501)
2501  FORMAT(/33H SELECT - (1) ANOTHER SPEED GROUP/10X.8A(2) QUIT)
        READ(1,*) NCASE
        IF(NCASE.EQ.2) GO TO 2510
        ANS=RWHD$(KW3)
        READ(KT,1002)(FN2(I),I=1,16),NN,AL9,ALF
        READ(KT,1003)(X(I),I=1,NN)
        WRITE(KW,2382)
        KPAGE = 0
        GO TO 2110
2510  ANS=CLOS$(KW1)
        IF(ANS) GO TO 2520
        WRITE(1,2511) KW1
2511  FORMAT('ERROR IN CLOSING FILE ON UNIT',15)

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```
2320  A.9=CLOS#A(KW2)
      IF(ANS) GO TO 2530
      WRITE(1,2511) KW2
2330  AN=CLOS#A(KW3)
      IF(ANS) GO TO 2540
      WRITE(1,2511) KW3
2540  CALL EXIT
      END
```

```

C
C
C
SUBROUTINE STAB(YO,RP,NS,NY,IT,KW,KPAGE)

C
C
C
CALCULATION OF
C
C
C
SYNS1,SYNS2          MINOR AND MAJOR STIFFNESS COEFFICIENTS
C
C
C
SYNB1,SYNB2          MINOR AND MAJOR CRITICAL DAMPING FACTORS
C
C
C
CRMA                  CRITICAL MASS FOR INSTABILITY
C
C
C
FRAT                  FREQUENCY RATIO OF INSTABILITY
C
C
C
FOR SYNCHRONOUS DATA (NY.EQ.1)
C
C
C
EE(K)                 MINOR/MAJOR RADIUS RATIO
C
C
C
OO(K)                 ORIENTATION ANGLE OF MAJOR AXIS
C
C
C
FOR ASYNCHRONOUS DATA (NY.EQ.2)
C
C
C
IMPLICIT REAL*8 (A-H,O-Z)
C
C
C
DIMENSION YO(8,1),Y(8),EE(2),OO(2)
C
C
C
PI = DATAN(1.0D-00)*4.0
C
C
C
IF (NS.EQ.3) GO TO 1000
C
C
C
FF = PI/3.0D+01*RP
C
C
C
GO TO 1
C
1000 IF (NY.EQ.1) GO TO 1010
C
C
C
FF = RP
C
C
C
GO TO 1
C
1010 FF = 1.0
C
C
C
DO 10 I=2,8,2
C
C
C
J=I-1
C
C
C
Y(J) = YO(J,IT)
C
C
C
10 Y(I) = FF*YO(I,IT)
C
C
C
Y34 = Y(3)**2+Y(4)**2
C
C
C
IF (Y34) 20,40,20
C
C
C
20 Y56 = Y(5)**2+Y(6)**2
C
C
C
IF (Y56) 30,40,30
C
C
C
COEFFICIENTS FOR PRINCIPAL MODE ANALYSIS
C
C
C
30 SKPA = Y(1)+Y(7)
C
C
C
SBPA = Y(2)+Y(8)
C
C
C
DKPA = Y(1)-Y(7)
C
C
C
DBPA = Y(2)-Y(8)
C
C
C
XKB = Y(3)*Y(6)+Y(4)*Y(5)
C
C
C
XKK = Y(3)*Y(5)
C
C
C
XBB = Y(4)*Y(6)
C
C
C
DKK=DKPA*DKPA+4.0*XKK
C
C
C
DKB=2.0*DKPA*DBPA+4.0*XKB
C
C
C
DBB=DBPA*DBPA+4.0*XBB
C
C
C
CALL PRINCE(DKK,DKB,DBB,ZK,ZB)
C
C
C
SYNS1=(SKPA-ZK)/2.0
C
C
C
SYNS2=SYNS1+ZK.
C
C
C
SYNB1=(SBPA-ZB)/2.0
C
C
C
SYNB2=SYNB1+ZB
C
C
C
SYNB1=SYNB1/DABS(SYNS1)/2.0

```

```

SYNB2=SYNB2/DABS(SYNS2)/2.0
IF (NY.EQ.2) GO TO 100
CRMA = (Y(1)*Y(8)+Y(7)*Y(2)-XKB)/SBPA
IF (CRMA.LE.0.0) GO TO 60
F2 = ((Y(1)-CRMA)*(Y(7)-CRMA)-XKK)/(Y(2)*Y(8)-XBB)
IF (F2.LT.0.0) GO TO 60
CRMA = CRMA/F2/386.4
FRAT = DSQRT(F2)
GO TO 50
40  SYNS1 = Y(7)
    SYNB1 = Y(8)
    SYNS2 = Y(1)
    SYNB2 = Y(2)
    IF (NY.EQ.2) GO TO 200
60  WRITE(KW,6001) RP,SYNS1,SYNB1,SYNS2,SYNB2
    GO TO 55
50  WRITE(KW,5002) RP,SYNS1,SYNB1,SYNS2,SYNB2,CRMA,FRAT
5002 FORMAT(1PD11.4,2(2D11.4,1X),2D11.4)
5010 KPAGE=KPAGE+1
    IF(KPAGE.LT.61) GO TO 70
    WRITE(KW,5050)
55  KPAGE=1
5050 FORMAT(1H1)
6001 FORMAT(1PD11.4,2(2D11.4,1X),23H UNCONDITIONALLY STABLE)
70  RETURN
C   ASYNCHRONOUS MODAL DATA PRINTOUT OF THE ANISOTROPIC CASE
100 K = 1
    KK = 1
    GX1 = (DKPA+ZK)/2.0
    GX2 = (DBPA+ZB)/2.0
    GY1 = Y(3)
    GY2 = Y(4)
105 U0 = DSQRT(GY1*GY1+GY2*GY2)
110 V0 = DSQRT(GX1*GX1+GX2*GX2)
    YY = GX1*U0+GY1*V0
    XX = GX2*U0-GY2*V0
    AA = DATAN2(YY,XX)
    CC = DCOS(AA)
    SS = DSIN(AA)
    X1 = U0*CC
    X2 = U0*SS
    Y1 = V0*CC
    Y2 = -V0*SS
    CALL WHIRL(U1,U2,V1,V2,X1,X2,Y1,Y2)
    CALL SHAPE(E,0,U1,U2,V1,V2)
    IF (E.GT.1.0) GO TO 150
    EE(K) = E
    OO(K) = 1.8E+02*(1.0+O/PI)
    IF (KK.EQ.2) GO TO 266
    IF (K.EQ.2) GO TO 130
    K = 2
    GX1 = GX1-ZK
    GX2 = GX2-ZB
    GO TO 110

```

```

130  IF (NS.NE.3) FF = RP/6.0D+01
      WRITE(KW,5100) FF,SYNS1,SYNB1,EE(1),OO(1),SYNS2,SYNB2,EE(2),OO(2)
5100  FORMAT(1X,1P9D10.3)
      GO TO 5010
150  WRITE(KW,5110)
5110  FORMAT(19H FAULTY MODAL SHAPE)
      CALL EXIT
C     ASYNCHRONOUS MODAL DATA PRINTOUT OF THE ISOTROPIC CASE
200  IF (Y34.NE.0.0.OR.Y56.NE.0.0) GO TO 250
      EE(1) = 0.0
      OO(1) = 9.0D+01
      EE(2) = 0.0
      OO(2) = 0.0
      GO TO 130
250  IF (Y(1).NE.Y(7).OR.Y(2).NE.Y(8)) GO TO 260
      EE(1) = 0.0
      OO(1) = 0.0
      IF (NS.NE.3) FF = RP/6.0D+01
      WRITE(KW,5200) FF,SYNS1,SYNB1,EE(1),OO(1)
5200  FORMAT(1X,1P4D10.3,16H DEGENERATE MODE)
      GO TO 5010
260  KK = 2
      IF (Y34.EQ.0.0) GO TO 270
      K = 1
      GX1 = Y(3)
      GX2 = Y(4)
      GY1 = Y(1)-Y(7)
      GY2 = Y(2)-Y(8)
      GO TO 105
266  IF (K.EQ.2) GO TO 130
      EE(2) = 0.0
      OO(2) = 0.0
      GO TO 130
270  EE(1) = 0.0
      OO(1) = 9.0D+01
      K = 2
      GX1 = Y(7)-Y(1)
      GX2 = Y(8)-Y(2)
      GY1 = Y(5)
      GY2 = Y(6)
      GO TO 105
      END

```

C
C
C

```
SUBROUTINE PRINCE(DKK,DKB,DBB,ZK,ZB)
  IMPLICIT REAL*8 (A-H,O-Z)
  DRE = DKK-DBB
  DIN = DKB
  DAMP = DSQRT(DRE*DRE+DIN*DIN)
  GO TO 40
30  DAMP = DABS(DKK)
   DRE = DKK
   DIN = 0.0
40  DARG = DATAN2(DIN,DRE)
   AMP = DSQRT(DAMP)
   ARG = DARG/2.0
   ZK = AMP*DCOS(ARG)
   ZB = AMP*DSIN(ARG)
  RETURN
  END
```

C
C
C

SUBROUTINE WHIRL(U1,U2,V1,V2,X1,X2,Y1,Y2)

IMPLICIT REAL*8 (A-H,O-Z)

C TRANSFORMS COMPLEX CARTESION REPRESENTATION (X1,X2),(Y1,Y2)
C INTO COMPLEX ROTATING REPRESENTATION (U1,U2),(V1,V2)

U1 = (X1-Y2)/2.0

U2 = (X2+Y1)/2.0

V1 = U1+Y2

V2 = U2-Y1

RETURN

END

C
C
C

SUBROUTINE SHAPE(E,O,U1,U2,V1,V2)

IMPLICIT REAL*8 (A-H,O-Z)

C
C CALCULATES MINOR/MAJOR RADIUS RATIO AND ORIENTATION FROM COMPLEX
C WHIRL COMPONENTS

UU = U1*U1+U2*U2

VV = V1*V1+V2*V2

WW = UU+VV

UM = UU/WW

VM = VV/WW

IF (UM.LT.1.0D-20) GO TO 10

IF (VM.LT.1.0D-20) GO TO 20

U = DSQRT(UU)

V = DSQRT(VV)

A1 = DATAN2(U2,U1)

A2 = DATAN2(V2,V1)

O = (A1-A2)/2.0

UV = U+V

E = (U-V)/UV

GO TO 40

10 IF (VM.LT.1.0D-20) GO TO 30

E = -1.0

15 O = -4.0*DATAN2(1.0D-00)

GO TO 40

20 IF (UM.LT.1.0D-20) GO TO 30

E = 1.0

GO TO 15

30 E = 2.0

40 RETURN

END

```

FUNCTION SHORT(ALT,ALD,ALF)
IMPLICIT REAL*8 (A-H,O-Z)
A2=ALF*ALF/3.0
KTIME=1
X=ALF*ALT
10 XX=2.0*X
YY=DEXP(-XX)
T=(1.0-YY)/(1.0+YY)
A=(1.0-T/X)/A2
IF(KTIME EQ.2) GO TO 20
A1=A
KTIME=2
X=ALF*ALD
GO TO 10
20 SHORT=A1/A
RETURN
END

```

C
C
C

```
      FUNCTION NWHERE(XX,X,NM)
      IMPLICIT REAL*8 (A-H,O-Z)
      DIMENSION X(1)
      N1=0
      MM = NM
      DO 10 I=2,MM
      Y=XX-X(I)
      IF(Y.GT.0.0) GO TO 10
      N1=I-1
      MM=I
10    CONTINUE
      IF(N1.EQ.0) N1=MM
      NWHERE=N1
      RETURN
      END
```

C
C
C

```
FUNCTION SPL(ZZ,Y1,DX,N)
  IMPLICIT REAL*8 (A-H,O-Z)
  DIMENSION ZZ(1),Y1(3,1)
  SPL=ZZ(N)+DX*(Y1(1,N)+DX*(Y1(2,N)+DX*Y1(3,N)/3.0)/2.0)
  RETURN
END
```

```

C
C
C
C
FUNCTION REFER (AA,BB,S1,S2,W)
CALCULATES REFERENCE FUNCTION

IMPLICIT REAL*8 (A-H,O-Z)
IF (S1.LT.0.0) GO TO 100
W1=DABS(AA)
W2=DABS(BB)
IF(W.EQ.0.0) GO TO 30
W1=W1*(W**S1)
W2=W2*(W**S2)
S3=S1-S2
IF(S3.GT.0.0) GO TO 10
IF(S3.GT.-1.00-00) W2=W2*W
REFER=W1+W2
IF(S3.LE.-1.00-00) GO TO 20
REFER=REFER/(1.00-00+W)
GO TO 20
10 REFER = W1*W2*(1.00-00+W)/(W+W1+W2)
20 RETURN
30 IF(S1.GT.0.0) GO TO 40
REFER = W1
GO TO 20
40 REFER = 0.0
GO TO 20
100 WRITE(1,1001)
1001 FORMAT(/3SH FAULTY DATA. NEAR FIELD EXPONENT =,1PD12.4)
CALL EXIT
END

```

C
C
C

C

```
SUBROUTINE TILT(Y,ROT,IT)
ROTATIONAL TRANSFORMATION OF IMPEDANCE MATRIX
IMPLICIT REAL*8 (A-H,O-Z)
DIMENSION ROT(1),Y(8,1)
YK11 = Y(1,IT)
YB11 = Y(2,IT)
YK22 = Y(7,IT)
YB22 = Y(8,IT)
YK12 = Y(3,IT)
YB12 = Y(4,IT)
YK21 = Y(5,IT)
YB21 = Y(6,IT)
DKPA = YK11-YK22
DBPA = YB11-YB22
SKXX = YK12+YK21
SBXX = YB12+YB21
Y(1,IT) = YK11*ROT(1)-SKXX*ROT(2)+YK22*ROT(3)
Y(2,IT) = YB11*ROT(1)-SBXX*ROT(2)+YB22*ROT(3)
Y(3,IT) = DKPA*ROT(2)+YK12*ROT(1)-YK21*ROT(3)
Y(4,IT) = DBPA*ROT(2)+YB12*ROT(1)-YB21*ROT(3)
Y(5,IT) = Y(3,IT)-YK12+YK21
Y(6,IT) = Y(4,IT)-YB12+YB21
Y(7,IT) = -Y(1,IT)+YK11+YK22
Y(8,IT) = -Y(2,IT)+YB11+YB22
RETURN
END
```

C
C
C

```
SUBROUTINE BASE(NBA,BMA,BST,BDA)
PEDESTAL PROPERTIES
IMPLICIT REAL*8 (A-H,C-2)
DIMENSION BMA(1),BST(1),BDA(1),BIN(2),R2(2)
WRITE(1,1001)
1001 FORMAT(/29HSELECT: (1) RIGID FOUNDATION/9X,13H(2) ISOTROPIC,
+26H FOUNDATION COMPLIANCE, OR/9X,27H(3) ANISOTROPIC FOUNDATION ,
+11HCOMPLIANCE?)
READ (1,*) NBA
IF (NBA.EQ.1) GO TO 1220
WRITE(1,1002)
1002 FORMAT(/31HSELECT: (1) RADIAL BEARING, OR/9X,12H(2) ANGULAR ,
+8HBEARING?)
READ (1,*) NTY
WRITE(1,1003)
1003 FORMAT(5X,27HENTER PEDESTAL WEIGHT (LB)?)
READ (1,*) BWT
IF (NTY.EQ.2) GO TO 105
BMA(1) = BWT/386.4
BMA(2) = BMA(1)
GO TO 120
105 WRITE(1,1004)
1004 FORMAT(5X,32HENTER CG OFFSET OF PEDESTAL (IN)/5X,6HAXIAL?,4X,
+21HVERTICAL? HORIZONTAL?)
READ (1,*) OZ,OX,OY
RRX = OZ*OZ
RRY = OZ*OZ
IF (NBA.EQ.2) GO TO 106
RRX = RRX+OX*OX
RRY = RRY+OY*OY
106 R2(1) = RRX*BWT
R2(2) = RRY*BWT
WRITE(1,1005)
1005 FORMAT(5X,49HENTER MOMENT OF INERTIA IN VERT PLANE (LB-SQ IN)?)
READ (1,*) BIN(1)
IF (NBA.EQ.3) GO TO 1006
BIN(2) = BIN(1)
GO TO 1010
1006 WRITE(1,1007)
1007 FORMAT(5X,50HENTER MOMENT OF INERTIA IN HORIZ PLANE (LB-SQ IN)?)
READ (1,*) BIN(2)
1010 DO 110 I=1,2
BMA(I) = (BIN(I)+R2(I))/386.4
110 CONTINUE
120 WRITE(1,1201)
1201 FORMAT(5X,43HENTER PEDESTAL STIFFNESS IN VERTICAL PLANE?)
WRITE(1,1202)
1202 FORMAT(5X,50H(LB/IN) FOR RADIAL BRG, OR (IN-LB/RAD) FOR ANG BRG)
READ (1,*) BST(1)
IF (NBA.EQ.3) GO TO 1203
BST(2) = BST(1)
```

```

      GO TO 1210
1203  WRITE(1,1204)
1204  FORMAT(5X,45HENTER PEDESTAL STIFFNESS IN HORIZONTAL PLANE?)
      WRITE(1,1202)
      READ (1,*) BST(2)
1210  WRITE(1,1211)
1211  FORMAT(5X,41HENTER PEDESTAL DAMPING IN VERTICAL PLANE?)
      WRITE(1,1212)
1212  FORMAT(5X,52H(LB-SEC/IN) FOR RAD BRG, OR (IN-LB-SEC/RAD) FOR ANG ,
+3HBRG)
      READ (1,*) BDA(1)
      IF (NBA.EQ.3) GO TO 1213
      BDA(2) = BDA(1)
      GO TO 1220
1213  WRITE(1,1214)
1214  FORMAT(5X,43HENTER PEDESTAL DAMPING IN HORIZONTAL PLANE?)
      WRITE(1,1212)
      READ (1,*) BDA(2)
1220  RETURN
      END

```

```

C
C
C
SUBROUTINE GOAT(FF,Y,IFRE,BM,BS,BD)
C
SUMMATION OF BEARING AND PEDESTAL COMPLIANCES
IMPLICIT REAL*8 (A-H,O-Z)
DIMENSION Y(8,1),BM(1),BS(1),BD(1)
DIMENSION AB(2,2),BB(2,2),BZ1(2),BZ2(2),DZ1(2),DZ2(2)
DIMENSION CB(2,2),DB(2,2),EB(2,2),FB(2,2)
C
C
ASSEMBLE BEARING IMPEDANCE

RP = FF*ATAN(1.00-00)/7.50-00
K = 0
DO 10 I=1,2
DO 10 J=1,2
K = K+1
KK = 2*K
K1 = KK-1
CB(I,J) = Y(K1,IFRE)
DB(I,J) = Y(KK,IFRE)*RP
10 CONTINUE
C
CALCULATE PEDESTAL IMPEDANCE ELEMENTS
C

RP2 = RP*RP
DO 20 I=1,2
BZ1(I) = BS(I)-BM(I)*RP2
BZ2(I) = BD(I)*RP
20 CONTINUE
C
COMBINE PEDESTAL AND BRG IMPEDANCES
C

DO 30 I=1,2
DO 30 J=1,2
IF (I.EQ.J) GO TO 25
AB(I,J) = CB(I,J)
BB(I,J) = DB(I,J)
GO TO 30
25 AB(I,J) = CB(I,J)+BZ1(I)
BB(I,J) = DB(I,J)+BZ2(I)
30 CONTINUE
C
INVERT
C

DD1 = AB(1,1)*AB(2,2)-BB(1,1)*BB(2,2)
+ -AB(1,2)*AB(2,1)+BB(1,2)*BB(2,1)
DD2 = AB(1,1)*BB(2,2)+BB(1,1)*AB(2,2)
+ -AB(1,2)*BB(2,1)-BB(1,2)*AB(2,1)
DD = DD1*DD1+DD2*DD2
DD1 = DD1/DD
DD2 = -DD2/DD
DO 40 I=1,2
K = 3-I
EB(I,I) = DD1*AB(K,K)-DD2*BB(K,K)
FB(I,I) = DD1*BB(K,K)+DD2*AB(K,K)
EB(I,K) = -DD1*AB(I,K)+DD2*BB(I,K)
FB(I,K) = -DD1*BB(I,K)-DD2*AB(I,K)

```

```

40  CONTINUE
C   POST MULTIPLY BY BRG IMPEDANCE
C
    DO 50 I=1,2
    DO 50 J=1,2
    AB(I,J) = 0.0
    BB(I,J) = 0.0
    DO 50 K=1,2
    AB(I,J) = AB(I,J)+EB(I,K)*CB(K,J)-FB(I,K)*DB(K,J)
    BB(I,J) = BB(I,J)+EB(I,K)*DB(K,J)+FB(I,K)*CB(K,J)
50  CONTINUE
C   PRE MULTIPLY BY PEDESTAL IMPEDANCE AND RESTORE Y
    K = 0
    DO 60 I=1,2
    DO 60 J=1,2
    K = K+1
    KK = 2*K
    K1 = KK-1
    Y(K1,IFRE) = BZ1(I)*AB(I,J)-BZ2(I)*BB(I,J)
    Y(KK,IFRE) = (BZ1(I)*BB(I,J)+BZ2(I)*AB(I,J))/RP
60  CONTINUE
    RETURN
    END

```

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